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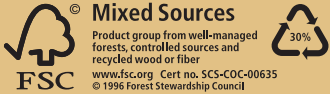
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# The President's Report

*July 1, 2009 - June 30, 2010*

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The Carnegie Institution was incorporated with these words in 1902 by its founder, Andrew Carnegie. Since then, the institution has remained true to its mission. At six research departments across the country, the scientific staff and a constantly changing roster of students, postdoctoral fellows, and visiting investigators tackle fundamental questions on the frontiers of biology, earth sciences, and astronomy.

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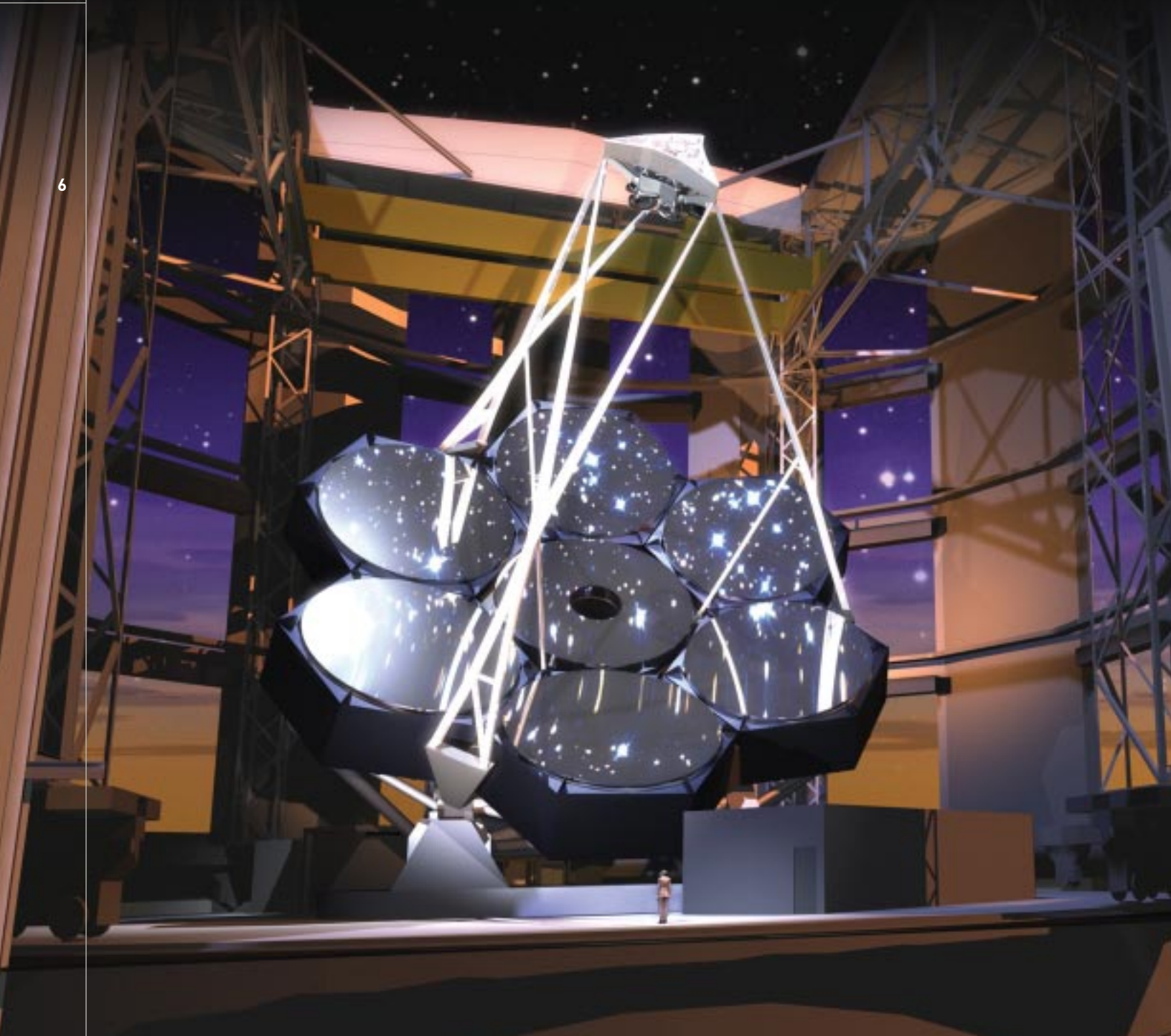


# Contents

The President's Commentary	6
Friends, Honors & Transitions	14
Research Highlights	24
Financial Profile	52
Personnel	59
Bibliography	77

# The President's Commentary

*Aspirations for the Future*





Carnegie president  
Richard A. Meserve  
*Image courtesy Jim Johnson*

The 25-meter Giant Magellan Telescope (left) will give astronomers unprecedented access to distant celestial objects enabling them to unravel some of the most vexing mysteries of the era, from the nature of dark matter and dark energy to how the universe evolved.  
*Image courtesy the GMTO*

At the November 2010 meeting of our board of trustees, we heard from the institution's directors about their scientific aspirations for the Carnegie departments. This exhilarating meeting revealed the potential for paradigm-shifting discoveries in several scientific disciplines, albeit with significant challenges that must be overcome if we are to realize them. I share some of these discussions here, borrowing liberally from the presentations of the Carnegie directors.

In astronomy, we reviewed the findings of a new report by the National Research Council to identify a program that will “set the astronomy and astrophysics community firmly on the path to answering profound questions about the cosmos.”<sup>1</sup> Panels were established covering five scientific frontiers, resulting in the definition of 20 key scientific questions that should be pursued over the next decade. Carnegie scientists, in reviewing the report, noted that the Giant Magellan Telescope (GMT) project, which Carnegie is spearheading with institutions of higher education in the United States and entities in Australia and Korea, addresses fully 18 of the 20 key scientific questions and 4 of the 5 frontier areas. The GMT telescope, which has now completed its design phase, is a telescope with a primary mirror, made of segments, with an aperture of 25 meters—far larger than any telescope now in existence. It will have the capability to study distant objects with unprecedented resolution. It promises to have a major impact in key areas such as understanding the connections between dark and luminous matter, tracking the baryon cycle in galaxies and the intergalactic medium, and identifying the first objects to light up the universe. The GMT, which will be equipped with adaptive optics to compensate for the disruptive effects of the Earth's atmosphere, will also have the capability to identify and determine the properties of nearby planets outside our own Solar System.

With these big opportunities in astronomy come some big challenges. There are technical hurdles to overcome in constructing a telescope of unprecedented size and capabilities, difficulty in raising capital in a time of constrained private and public resources, and the need to forge an international partnership that harnesses the capacities of several countries and institutions. I am pleased that Carnegie and our partners are facing these challenges directly, and we are optimistic that we will meet and overcome them in the coming decade.

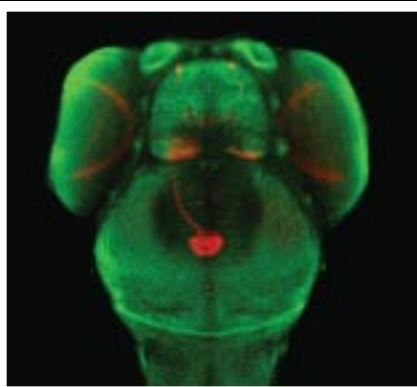
<sup>1</sup>Committee for a Decadal Survey of Astronomy and Astrophysics, Board on Physics and Astronomy, Space Studies Board, Division on Engineering and Physical Sciences, *New Worlds, New Horizons in Astronomy and Astrophysics* (Washington, D.C. National Research Council of the National Academies, The National Academies Press, 2010)



Carnegie's Department of Embryology seeks to develop a greater understanding of the fundamental mechanisms governing the development of living organisms. Its scientists expect, along the way, to find that some of the fundamental assumptions about the genome are incomplete. For example, they expect we will find that there are novel biological mechanisms using parts of the genome whose significance is not currently understood (only about 2% of the human genome constitutes genes). They seek to identify new ways in which the genomes of somatic cells systematically acquire differences during development from each other and from germ line cells. They seek to expand our understanding of the operation of stem cells. And they seek to discover new mechanisms for the regulation of genome replication, new means for information storage and retrieval in the neural system, and new mechanisms involved in cancer and evolution.

In addition to these revolutionary tasks, Carnegie scientists will continue to carry out more predictable research. They seek to understand the structure at single-cell resolution of all tissues (including the nervous system) of the model organisms (e.g., mice, fruit flies, zebrafish) that are the focus of the department's research. They seek to understand intercellular communication within tissues. They seek to develop new means to understand physiological cellular activities and metabolism. And finally, they seek to document the underlying unity of these various processes between species, as well as exceptions, in order to understand how the biological world evolved from a common Precambrian ancestor.

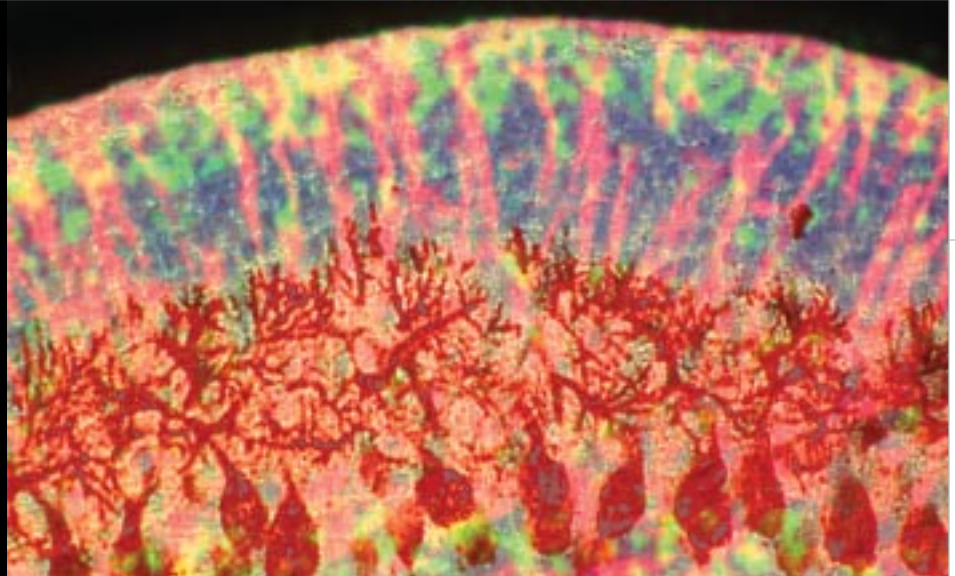
Department directors discussed their visions for their departments at the November board meetings. From left to right: Observatories' Wendy Freedman; Embryology's Allan Spradling; Plant Biology's Wolf Frommer; Global Ecology's Chris Field; the Geophysical Laboratory's Rus Hemley; and Terrestrial Magnetism's Sean Solomon.



The above image from Embryology's Halpern lab, shows molecular differences between left and right sides of a larval zebrafish brain in red.

*Image courtesy Marnie Halpern*

Department of Embryology scientist Chen-Ming Fan uses the mouse as a model organism. The image (above right) is a developing cerebellum in a mouse. The top green layer is the proliferating granule stem cells; the blue cells below them are the differentiating granule cells. Pink fibers through the granules are the Bergmann glial fibers, which guide the differentiating granule cells to climb down into the inner chamber. The dark trees with bulbs are the Purkinje cells, to which the granule cells make connections. The yellow cells between the bulbs are the proliferating Bergmann glia stem cells. The granule cells and the Purkinje cells work together to modulate the body's fine motor activity.



Realizing these dreams will require new equipment for sequencing, microscopy, and biochemistry, along with some renovation and expansion of the department's animal facilities. This is a time of extraordinary advance in biology and the department is at the forefront.

The quest of the Department of Plant Biology is to unlock the mysteries of plant life, organisms that constitute the foundation for all life on Earth. They use advanced technologies in biology to address a myriad of mysteries: How sunlight is absorbed and used by plants to produce biomass, how inorganic nutrients are captured and converted into organic matter using the energy from light, how single cells and the plant body are formed, how the environment shapes plant growth and development and, in turn, how plants interact with and shape the environment. Our researchers seek to extend our knowledge of the fundamental biological mechanisms critical for plant growth and development through basic research, a hallmark of all Carnegie science. In addition, the department's scientists are pursuing several overarching research initiatives. They explore how plants evolved on Earth, focusing on the emergence of novel plant-specific features. And they are studying the "hidden" half of plants—namely, the underground root system—and its interaction with the environment. Finally, they seek to harness sophisticated bioinformatics tools to develop a deeper understanding of the genes that regulate critical plant functions. The opportunities are tremendous, yet, to achieve their goals, we must raise funds to renovate research facilities and to enhance technological infrastructure in the areas of advanced imaging and bioinformatics.

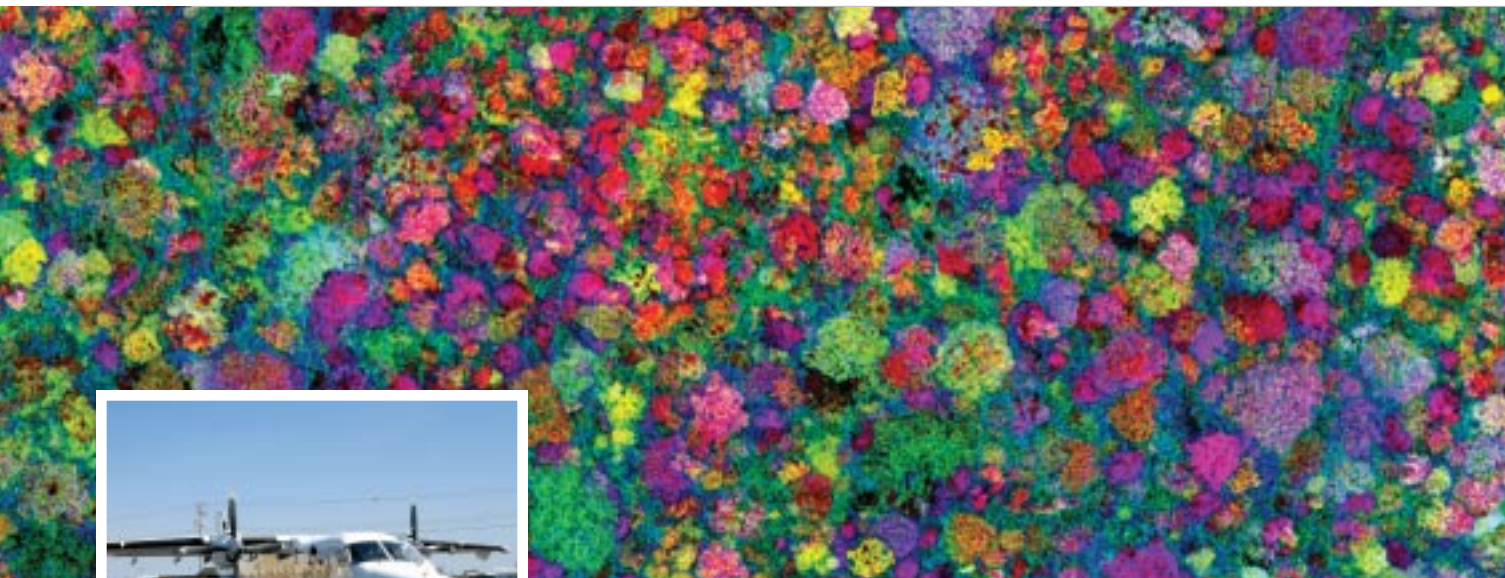


*Arabidopsis thaliana* (above left) is a tiny, mustard-like weed with a rapid 6-week life cycle making it ideal for studying development, photosynthesis, disease defenses, and plant behaviors. The genome sequence of this model plant was completed in 2000.

Plant Biology researchers use advanced imaging techniques, such as spinning disk microscopes (above) with superior sensitivity.

The Department of Global Ecology, founded in 2002, has already established itself as one of the leading enterprises pursuing integrated Earth-system science. Its aim is to answer fundamental questions about major components of the Earth's system, including such complex issues as the consequences of changes in the atmospheric concentration of greenhouse gases. It thereby seeks to establish the scientific foundations for a sustainable future for the planet. Some of the recent contributions of the department's scientists include a study of the impacts of recent global warming on agricultural yields, measurement by sophisticated remote-sensing techniques of the scale of global forest degradation, assessment of the impacts of ocean acidification, study of the impacts of various techniques to counteract some of the effects of growing greenhouse gas accumulation (termed geoengineering), and a study of the climate feedbacks resulting from changes in forests. The overall goal of this research is to understand the forces that shape the behavior of the Earth's systems. Our challenge is to build a department that has resources that are commensurate with the scope of the problems it is tackling.

One remarkable tool developed at Global Ecology is the Carnegie Airborne Observatory. This system, which is mounted on an aircraft, enables rapid broad-scale ecological assessments of the surveyed terrain. It combines a laser-ranging instrument that enables the measurement of canopy structure, along with a spectroscopic instrument that enables the remote identification of plant species. This tool could provide a critical and unique capability to understand the changing conditions in, for example, tropical forests.



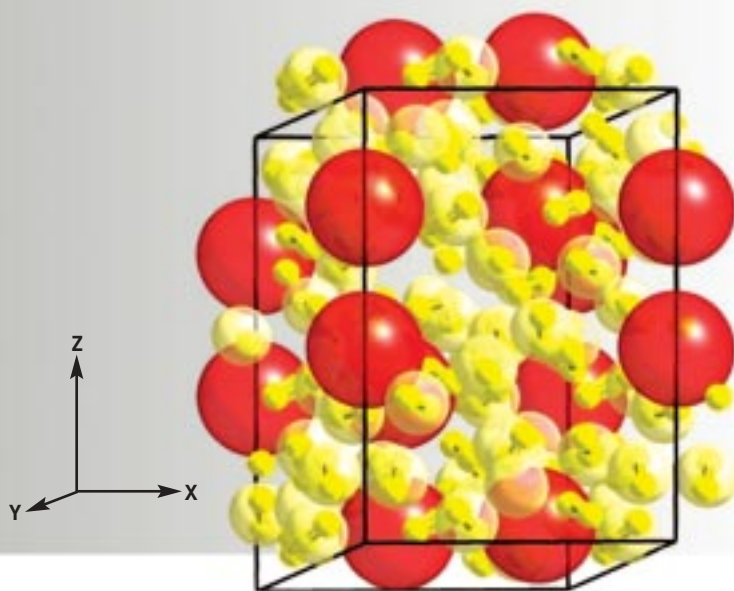
The Carnegie Airborne Observatory (inset) makes large-scale ecological assessments of tropical forests. At right is a high-resolution map of the chemical diversity of vegetation in Panama.

*Image courtesy Greg Asner*

The scientists at the Geophysical Laboratory have shown repeatedly that breakthroughs in our understanding of materials and of geophysics arise when we explore the behavior of materials under extreme conditions, such as extremes of temperature or pressure. They seek to explore fundamental questions: What new physics will appear when atoms are brought and kept extremely close together? What are the extremes of chemistry—i.e., reactivity, inertness, bonding, strength, and kinetics? How far can we extend the limits of material behavior and make new materials for efficient yet benign energy generation, conversion, and transfer? How can we understand the formation and evolution of Earth, super-Earths, and other celestial bodies in terms of the full range of their extreme environments? What is the fate of elements such as carbon deep within planets? What are the extreme limits of biology? What roles do extreme environments play in the origin and evolution of life? How do they enlighten our search for life beyond Earth's surface?

The Geophysical Laboratory pursues its research through a growing network of relationships, laboratories, and field sites. It has successful programs at Argonne National Laboratory, Brookhaven National Laboratory, and most recently, Oak Ridge National Laboratory, for the conduct of research using unique tools at these laboratories that were developed in partnership with Carnegie scientists. It seeks to expand these relationships and establish new ones in a network of observatories as it strengthens the instrumentation base and capabilities at our facilities on Broad Branch Road.

The Department of Terrestrial Magnetism pursues a broad sweep of questions that address the formation and evolution of planets, including our own. Scientists in that department are grouped in three broad areas—astronomy, geochemistry and cosmochemistry, and geophysics. Within these groups, fundamental theoretical and obser-



vational questions abound, such as the theory of formation of gas-giant, ice-giant, and rocky planets; the chemistry and chronology of early Solar System material, including meteorites, interplanetary dust particles, and samples from cometary and planetary bodies; and those aspects of Earth structure relating to the formation and evolution of continents. Challenges for that department include the need for additional fellows, equipment, computational resources, and skilled technical support.

As the foregoing shows, the scientific dreams of our staff are varied and exciting. It nonetheless is important to note that we do not aim to script our future projects in ways that constrain us. During our discussion, Allan Spradling, the director of the Department of Embryology, provided a view that I share: “[Our] departments do not exist to solve specific [scientific] problems . . . Instead, they strive to do the most important work in their field at a particular moment in time, work that will maximally advance the field’s internal development. Unfortunately, it is usually not clear what that work is until it is almost completed. . . . [T]he flexible Carnegie style has allowed small departments to have an outsized influence, and arguably has been the secret of the institution’s success over most of its history.” While constantly setting ambitious scientific targets, we seek to maintain the flexibility to pursue the unexpected. Indeed, it is the startling moment of clarity arising from a surprising result that often yields the greatest scientific advance.

Of course, the achievement of the ambitious dreams of our scientists requires resources. Our endowment is recovering from the economic decline of 2008, but not sufficiently as yet to enable significant new spending. We have fared well in support from the federal government and from foundations—a testament to the skills of our scientists—



Scientists at the Geophysical Laboratory (GL) found for the first time that high pressure can be used to make a unique hydrogen-storage material (left). They found that the normally unreactive, noble gas xenon combines with molecular hydrogen ( $H_2$ ) under pressure to form a previously unknown solid with unusual bonding chemistry. The discovery debuts a new family of materials. Other GL researchers were able to watch nanoparticles grow from the earliest stages of their formation (right). Nanoparticles are the foundation of nanotechnology and their performance depends on their structure, composition, and size. Researchers will now be able to develop ways to control the conditions under which they are grown.



Terrestrial Magnetism's Paul Butler and team find planets around other stars. Their ultimate goal is to find other Earths. This artist's rendition shows the potentially habitable Earth-sized planet his team recently found. It is one of two new planets discovered around the star Gliese 581, some 20 light-years away.

*Image courtesy NASA, artwork by Lynette Cook*

but we should not expect handsome future growth from these sources. We are clearly entering a period of fiscal stringency at all levels of government. And foundations are recovering from the same endowment declines suffered by Carnegie and most universities, so prudence in their future commitment of resources seems probable.

Nonetheless, I am optimistic that the expansion of our scientific reach will be achieved. I observe the remarkable success of Carnegie science, as revealed by the steady flow of remarkable discoveries from all our departments. (One measure of this success is the extensive listing of scientific publications in major journals that is set out elsewhere in this volume.) Despite our small size, we are very significant contributors in the fields in which we work. Given the important role of science in building a sustainable and productive future, I am confident that the necessary resources will be found.

Andrew Carnegie founded the institution with the intention that it shall "in the broadest and most liberal manner, encourage investigation, research, and discovery." We are filling the role that Andrew Carnegie intended for us. We will continue to enrich the storehouse of scientific knowledge on into the future, as we have in the past. As the conversation with Carnegie directors has revealed, we do not lack exciting new scientific terrain to explore.

*Richard A. Meserve*

# Friends, Honors & Transitions

14



# Carnegie Friends



## Annual Giving

### The Barbara McClintock Society

An icon of Carnegie science, Barbara McClintock was a Carnegie plant biologist from 1943 until her retirement. She was a giant in the field of maize genetics and received the 1983 Nobel Prize in Physiology/Medicine for her work on patterns of genetic inheritance. She was the first woman to win an unshared Nobel Prize in this category. To sustain researchers like McClintock, annual contributions to the Carnegie Institution are essential. The McClintock Society thus recognizes generous individuals who contribute \$10,000 or more in a fiscal year, making it possible to pursue the highly original research for which Carnegie is known.

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## Robert G. Goelet

Trustee Robert G. Goelet has been a guiding force on the Carnegie board of trustees for more than a quarter of the institution's existence. When he was elected in 1980, he was president of Goelet Realty Company, vice president of Goelet Estate Company, director of the Chemical Bank, and president of the American Museum of Natural History. His unique blend of business and nonprofit experience, along with his love of biology, made him a perfect fit for Carnegie.

Goelet is a member of the Finance Committee, a post he has held since 1981. In the early 1980s he was also a member of the Nominating Committee, chairing it in 1984. He has been an integral part of the institution's history and a contributor to its scientific prosperity, helping steer it through the business challenges of the Observatories' Magellan Telescope Project. He was involved with the relocation of the Geophysical Laboratory (GL) and the Department of Terrestrial Magnetism to one site, and has watched GL become a driving force in a half dozen major international research alliances and Terrestrial Magnetism evolve into a powerhouse for planetary studies. He saw the launching of Carnegie's educational programs, First Light and the Carnegie Academy for Science Education, witnessed the construction of the Maxine Singer Building at Embryology, and was party to establishing the first new department in over 80 years, the Department of Global Ecology.

For three decades, Goelet has consistently supported the institution's initiatives. He has generously contributed to every capital campaign, challenge grant, and annual fund drive, and he has supported instrumentation, buildings, the Global Ecology fund, and more. He is a member of the Edwin Hubble Society.



★ Robert Goelet

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Gordon and Betty Moore Foundation  
Alfred P. Sloan Foundation

**\$100,000 to \$999,999**

The Ahmanson Foundation  
The Gayden Family Foundation  
The Hearst Foundation, Inc.  
Andrew W. Mellon Foundation  
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**\$10,000 to \$99,999**

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The William and Nancy Turner Foundation  
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## William K. Gayden

In 1998 David Swensen, then chairman of the Finance Committee, recommended that Bill Gayden, founder, chairman, and chief executive officer of Merit Energy Company, present information about his company to the board as a possible Carnegie investment. Merit, founded in 1989, is a privately owned oil and gas company that acquires and exploits mature petroleum reserves. Little did anyone suspect that Gayden harbored a passionate interest in astronomy and would later become a valued board member. Everyone on the Finance Committee was captivated by Gayden's presentation, not just because of the success of the company, but because they found him to be an independent and creative thinker.

Some years after Gayden's presentation, the Nominating Committee invited him to join the board. By that time Gayden had become familiar with Carnegie's high-risk, high-reward science—a natural fit for a successful entrepreneur. Gayden was elected to the board in 2002. Since then he has served as a member of the Research and Budget and Operations committees. He also served as a member and then chairman of the Audit Committee. His business instincts and insights were critical as he helped the institution navigate the rough waters it encountered as it modified its new business practices.

From the very beginning, Gayden has been a particularly strong advocate for the bold and ambitious Giant Magellan Telescope project. The one-of-a-kind venture, on course for completion in 2019, has benefited tremendously from his gifted counsel and support. Gayden has consistently supported other high-priority needs at Carnegie over the years. He is a member of the Vannevar Bush Society.



★ William K. Gayden

### \$500 to \$9,999

The Abell Foundation  
Peter and Julia Brennan Fund  
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Mulago Foundation  
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#### Over \$1,000,000

National Aeronautics and Space Administration  
National Science Foundation  
U.S. Department of Energy  
U.S. Public Health Services-National Institutes of Health

#### \$100,000 to \$1,000,000

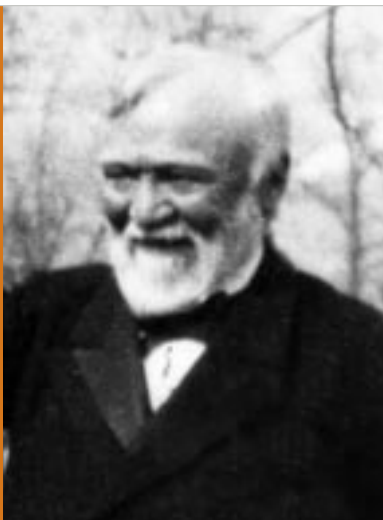
U.S. Office of Naval Research

#### \$10,000 to \$99,999

U.S. Department of Agriculture, Forest Service  
U.S. Army

## Carnegie Institution for Science

★ Andrew Carnegie



★ Edwin Hubble



★ Vannevar Bush



## Lifetime Giving Societies

## The Carnegie Founders Society

Andrew Carnegie, the founder of the Carnegie Institution, established it with a gift of \$10 million. Although he ultimately gave a total of \$22 million to the institution, his initial \$10 million gift represents a special level of giving. In acknowledgment of the significance of this initial contribution, individuals who support Carnegie's scientific mission with lifetime contributions of \$10 million or more are recognized as members of the Carnegie Founders Society.

Caryl P. Haskins\*

William R. Hewlett\*

## The Edwin Hubble Society

The most famous astronomer of the 20th century, Edwin Hubble, joined the Carnegie Institution in 1919. Hubble's observations shattered our old concept of the universe. He proved that the universe is made of collections of galaxies and is not just limited to our own Milky Way—and that it is expanding. This work redefined the science of cosmology. Science typically requires years of work before major discoveries like these can be made. The Edwin Hubble Society honors those whose lifetime support has enabled the institution to continue fostering such long-term, paradigm-changing research by recognizing those who have contributed between \$1,000,000 and \$9,999,999.

D. Euan and Angelica Baird

Michael and Mary Gellert

Robert G. and Alexandra C. Goelet

William R. Hearst III

Richard E. Heckert\*

Kazuo and Asako Inamori

Burton and Deedee McMurtry

Jaylee M. Mead

Cary Queen

Deborah Rose, Ph.D.

William J. Rutter

Thomas and Mary Urban

Sidney J. Weinberg, Jr.\*

## Second Century Society

### The Vannevar Bush Society

Vannevar Bush, the renowned leader of American scientific research of his time, served as Carnegie's president from 1939 to 1955. Bush believed in the power of private organizations and wrote in 1950, "It was Andrew Carnegie's conviction that an institution which sought out the unusual scientist, and rendered it possible for him to create to the utmost, would be worth while [sic] . . ." He further said that "the scientists of the institution . . . seek to extend the horizons of man's knowledge of his environment and of himself, in the conviction that it is good for man to know." The Vannevar Bush Society recognizes individuals who have made lifetime contributions of between \$100,000 and \$999,999.

Anonymous (3)  
 Bruce and Betty Alberts  
 Daniel Belin and Kate Ganz  
 Didier and Brigitte Berthelemot  
 Gary P. and Suzann A. Brinson  
 Donald and Linda Brown  
 A. James Clark  
 Tom and Anne Cori  
 Jean and Leslie Douglas  
 Bruce Ferguson and Heather Sandiford  
 Stephen and Janelle Fodor  
 William and Cynthia Gayden  
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 Richard A. and Martha R. Meserve  
 Al and Honey Nashman  
 Evelyn Stefansson Nef\*  
 Vera C. Rubin  
 Allan R. Sandage\*  
 Christopher and Margaret Stone  
 William and Nancy Turner

The Carnegie Institution is now in its second century of supporting scientific research and discovery. The Second Century Society recognizes individuals who have remembered, or intend to remember, the Carnegie Institution in their estate plans and those who have supported the institution through other forms of planned giving.

Bradley F. Bennett\*  
 Richard Buynitzky\*  
 Eleanora K. Dalton  
 Nina V. Fedoroff  
 Kirsten H. Gildersleeve  
 Robert and Margaret Hazen  
 Paul and Carolyn Kokulis  
 Gilbert and Karen Levin  
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 Allan R. Sandage\*  
 Leonard Searle\*  
 Maxine and Daniel Singer  
 John R. Thomas, Ph.D.  
 Hatim A. Tyabji

\* Deceased

*Members were qualified with gift records we believe to be accurate.  
 If there are any questions, please call Mira Thompson at 202.939.1122.*

# Honors & Transitions

## Honors

### Administration

Carnegie president **Richard Meserve** was appointed to the Blue Ribbon Commission on America’s Nuclear Future by Secretary of Energy Steven Chu in 2009. He also received an honorary doctorate from Washington College.

**Toby Horn**, codirector of the Carnegie Academy for Science Education, received the 2009 Bruce Alberts Award for Excellence in Science Education from the American Society of Cell Biology in December 2009.

### Embryology

Staff member **Douglas Koshland** was elected to the National Academy of Sciences in April 2010.

Research technician **Dianne Williams** received Carnegie’s Service to Science Award in May 2010.

### Geophysical Laboratory

Director Emeritus **Charles Prewitt** received the first IMA Medal for Excellence in Mineralogy from the International Mineralogical Association at the Goldschmidt Conference in 2009.

Staff member **Yingwei Fei** was elected a 2010 fellow of the American Geophysical Union.

### Global Ecology

Department director **Christopher Field** was elected to the American Academy of Arts and Sciences in April 2010. He was also awarded the Heinz Award in September 2009.

Staff member **Kenneth Caldeira** was elected a 2010 fellow of the American Geophysical Union.

### Observatories

**Frank Perez**, site manager/telescope engineer, received Carnegie’s Service to Science Award in May 2010.

### Plant Biology

Director Emeritus **Winslow Briggs** was awarded the 2009 International Prize for Biology by the Japan Society for the Promotion of Science.

### Terrestrial Magnetism

Staff member **Steven Shirey** was elected a 2010 fellow of the American Geophysical Union.

## Transitions

Trustee emeritus **Richard Heckert** died in January 2010.

Staff member **Paul Silver** of Terrestrial Magnetism died in a car accident with his daughter on August 7, 2009.

Embryology staff associate **Judith Yanowitz** became an assistant professor at the Magee-Womens Research Institute in Pittsburgh in November 2009.

**Martin Jonikas** joined the Department of Plant Biology as a young investigator in 2010.



★ Richard Meserve



★ Toby Horn



★ Douglas Koshland



★ Dianne Williams



★ Charles Prewitt



★ Yingwei Fei



★ Christopher Field



★ Kenneth Caldeira



★ Frank Perez



★ Winslow Briggs



★ Steven Shirey



★ Richard Heckert



★ Paul Silver



★ Judith Yanowitz



★ Martin Jonikas

# Research Highlights



# Embryology

*Deciphering the Complexity of Cellular, Developmental, and Genetic Biology*



## Watching Estrogen Turn On

Sex hormones bind to receptors, activating genes that play roles in many physiological activities. For example, estrogen receptors are activated when bound by naturally occurring estrogens as well as by synthetic chemicals that mimic estrogen. In turn, bound receptors enter the cell's nucleus, where they bind to specific sequences of DNA and activate genes. Carnegie scientist Daniel Gorelick in Marnie Halpern's laboratory has developed a new method for observing estrogen-receptor activity in live fish. The tool could help scientists understand the reason for the high number of intersex fish—males that show female characteristics—recently found in rivers and streams

across the United States. Of particular interest to Gorelick and Halpern, however, is the possibility that this tool might also help elucidate currently unappreciated roles of estrogen in brain development and behavior.

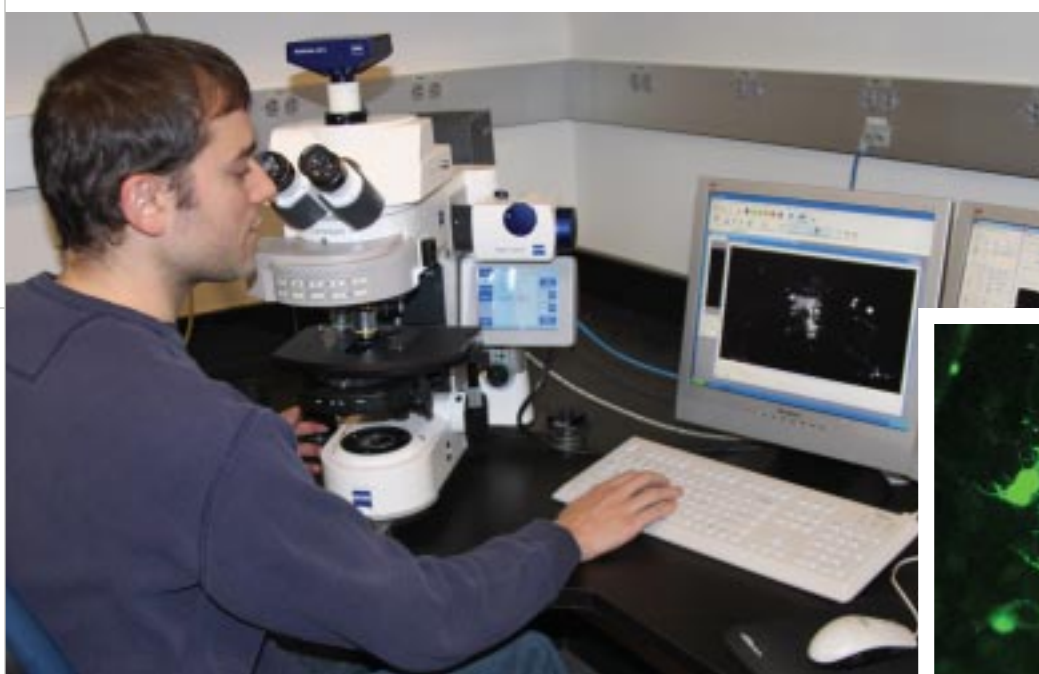
The estrogen-response system is involved in lipid metabolism, bone growth, glucose metabolism, and reproduction. Estrogen and estrogen receptors also modulate mating behaviors and aggression. To understand the physiological effects of estrogen, it is crucial for scientists to develop the best tools and processes for observing when and in which cells receptors become activated and for learning the consequences of activation.

Gorelick created transgenic zebrafish larvae that turn on a green fluorescent protein in cells where estrogen receptors are activated in the presence of estrogen. Activation was observed in the liver and the brain, as expected. Green cells were also found in other tissues, such as olfactory neurons and heart valves, where less sensitive tests have not detected activated estrogen receptors.

The researchers recognized the importance of proving that the new method was specific as well as sensitive. Fluorescent labeling was activated by natural and synthetic estrogens, but not by other sex hormones. Also, fluorescence was inhibited by compounds that are known



(Left) In a five-day-old zebrafish larva, the liver glows as estrogen receptors are activated. The Gorelick-Halpern method is the first of its kind for observing estrogen signaling in live fish. (Center and right) After swimming in water containing estrogen, the liver glows in an adult fish. On the right, a special fluorescence microscope is used to visualize estrogen receptor activation.

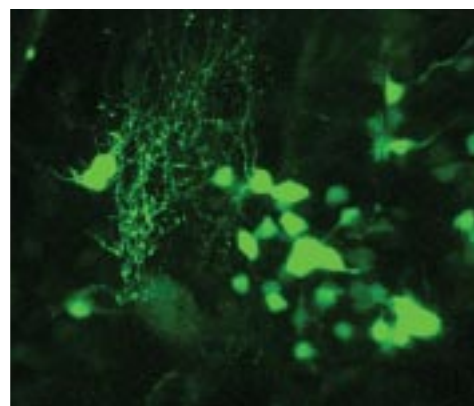


(Above) Daniel Gorelick uses a fluorescence microscope to image estrogen-responsive neurons in the zebrafish brain.

*Image courtesy Bill Kupiec*

(Right) Neurons sensitive to estrogen are shown in the brain of this live larva.

*Image courtesy Daniel Gorelick and Marnie Halpern*



to antagonize estrogen receptors. Together these results demonstrate that the system designed by Gorelick and Halpern is specific to estrogen and estrogen receptors.

There are many potential applications for these specially designed zebrafish. One of the most exciting is studying how water pollution by estrogenic compounds acts on susceptible animals, for example, by identifying affected tissues. Another use of these fish of particular interest to Gorelick and Halpern will be to monitor how different populations of nerve cells are activated during behaviors modulated by estrogen.

## Muscle Stem Cell Surprise

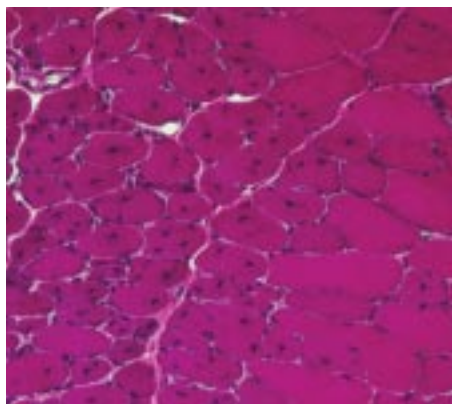
Some surprising results from Carnegie molecular biologists may have important implications for the treatment of muscular dystrophy, aging-related muscle atrophy, and regenerative medicine. Chen-Ming Fan and Christoph Lepper have demonstrated that the genes in charge of regulating the production of embryonic muscle stem cells

are not necessary to regenerate adult skeletal muscles after injury or damage.

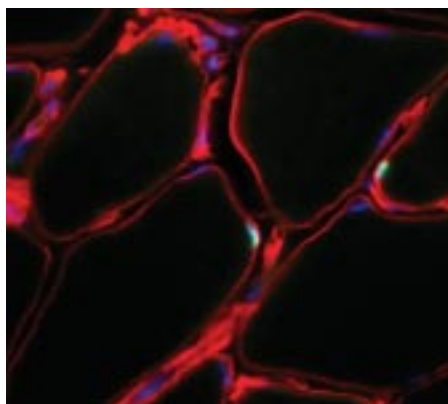
Conventional wisdom had led researchers to believe that regeneration of skeletal muscle tissue would mimic the process of embryonic muscular development. Following this logic, the Carnegie team studied *Pax3* and *Pax7*, two “master regulator” genes that previous research had demonstrated are essential for making embryonic and neonatal muscle stem cells in mice.

Using sophisticated genetic tools, the team was able to look at the activities of these two genes at various stages of muscle growth in live mice. Their results showed that specialized embryonic protomuscle cells directly regulated by *Pax3* and *Pax7* do develop into adult muscle stem cells. But, contrary to expectations, shortly after the mice were born these genes were found to be no longer necessary for adult muscle stems cells to make new muscles. This finding surprised Lepper and Fan, and was a big shock for muscle researchers worldwide.

Further study allowed the team to narrow down the period of time when *Pax3* and *Pax7* are still important for



(Above left) This image is a stained cross section of skeletal muscle tissue 10 days after an intramuscular injection of toxic snake venom. The fibers on the left show centrally located nuclei, a hallmark of regenerative muscle fibers. The fibers on the right are old, mature fibers that weren't injured by the toxin injection.



(Above right) This is a cross section of mature skeletal muscle, which was reacted with antibodies and stained to label all nuclei. The two green nuclei were bound to the Pax7 antibody, indicating that they are so-called satellite cells. Their name comes from their location, which is "orbiting" the muscle fiber.

*Images courtesy Christoph Lepper*

(Far right) Chen-Ming Fan of the Department of Embryology holds research mice in the laboratory.

*Image courtesy Chen-Ming Fan*



generating muscle stem cells after birth. It turns out that these embryonic stem cell genes are required only during the first three weeks of life. Afterward, *Pax3* and *Pax7* apparently hand their duties off to a different set of genes.

In mice older than three weeks, this second, unidentified, set of genes would be activated to rebuild muscles after damage due to trauma or exercise. Going forward, the researchers hope to better understand this transition-

al period when the embryonic genes become inactive and a new set of regulators takes over.

The finding that some adult tissues use genes that are different from the ones juvenile tissues use to repair themselves is fundamentally important. Fan and Lepper's discovery also illustrates the importance of understanding the intricacies of stem cell biology before making clinical decisions about cell-based therapies for muscle diseases. □

# Geophysical Laboratory

*Probing Planetary Interiors, Origins, and Extreme States of Matter*



## Whiskers 'n' Water on the Moon

It was a big year for the Moon. Researchers at the Geophysical Laboratory (GL) found evidence for more water in its interior than previously known. They also discovered carbon in the form of graphite “whiskers.” The whiskers could have formed only in high temperatures, so presumably they were produced by the impactors from the late heavy bombardment of 3.8 billion years ago. That also means the Moon potentially holds a record of the carbon input to the Earth-Moon system as life was beginning to emerge.

For several decades scientists have thought the Moon was dry. Its bulk water content was thought to be less than 1 part per billion—a million times drier than the interiors of Earth and Mars. The team of scientists examined the mineral apatite in two Apollo samples and in a lunar meteorite. GL postdoctoral fellow Francis McCubbin and team enlisted Erik Hauri of Terrestrial Magnetism to help with the aid of his secondary ion mass spectrometer. The researchers combined their measurements with models that characterize how the material crystallized as the Moon cooled and found that the water content ranged from 64 parts per billion to 5 parts per million.

The prevailing belief is that the Moon was created by a giant-impact event; a Mars-sized object hit the Earth some 3.8 billion years ago and the ejected material coalesced into the Moon. The Carnegie scientists determined that water was likely present as the hot magma started to cool and crystallize—meaning water is native to the Moon. This result was unexpected, because volatiles like water and carbon were vaporized under the heat and shock of the impact.

Until now, scientists thought that the trace amounts of carbon on the Moon’s surface came from the solar wind. Andrew Steele’s team analyzed thin lunar rock slices and determined that carbon also survived the impact. They found minerals and carbon beneath the surface and were very surprised to find graphite and graphite whiskers. Previously, the only carbon identified on the Moon came from solar wind implantation.

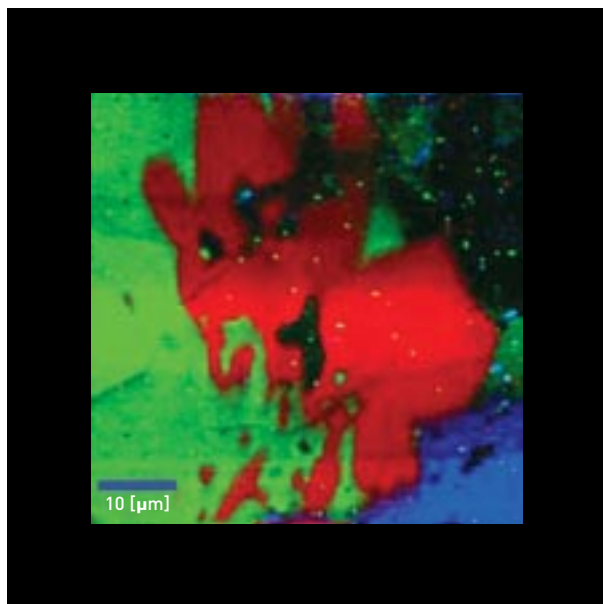
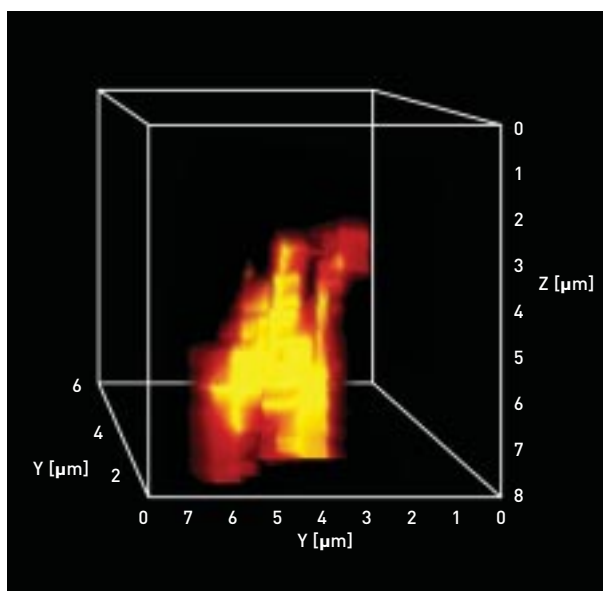
The scientists ruled out that the graphite was from contamination because it is imbedded in the minerals and because graphite whiskers in the absence of water form only under very hot conditions, between 1830°F and 6500°F (1273-3900 K). The particles are also much larger than those of any solar-wind-implanted carbon. They think the graphite either came from the impacting object or that it condensed from the carbon-rich gas that was released during impact.

(Top right) This three-dimensional image is a depth profile of graphite from a lunar sample to 8 millionths of a meter. From *Science*, vol. 329, 5987, p. 51, July 2, 2010.

*Reprinted with permission from AAAS.*

(Bottom right) This is a Raman multispectral image of Apollo sample 15058. The hydroxyl-bearing apatite is shown in red.

*Image courtesy American Mineralogist.*



## Getting to the Core of the Matter

Bizarre behavior emerges when matter is subjected to extreme pressures and temperatures—chemical bonds morph, crowded electrons become erratic, and new materials can be forged. One method for analyzing samples at extreme conditions is squeezing them in a diamond anvil cell and using X-ray diffraction to reveal atomic structure; but X-ray diffraction has its limitations. Currently, a team at the GL is revolutionizing the field by harnessing the next-generation neutron sources for studies of materials at unprecedented pressures and temperatures.

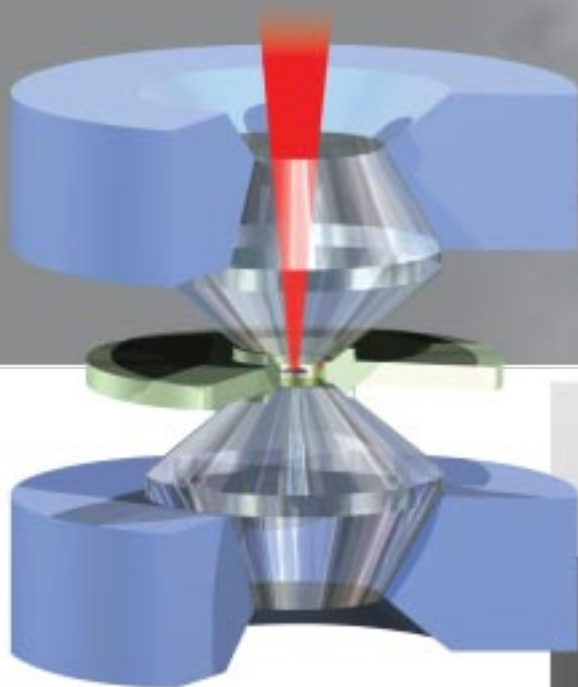
X-ray diffraction works by interacting with the electron cloud surrounding an atom. In contrast, neutrons interact directly with the nucleus, yielding many advantages: enabling the detection of positions of the lighter elements (particularly hydrogen, which is invisible to X-rays) near heavier ones, directly measuring magnetism, and facilitating the study of liquids, nanocrystals, and glasses. Neutrons are not widely used because of the comparative weakness of neutron sources relative to those of X-rays. The neutron landscape changed dramatically in August 2009, however, when the new Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) exceeded 1 megawatt of power, eclipsing the European 163-kilowatt record. Malcolm Guthrie is leading the Carnegie neutron team at the new source as part of the DOE-supported center for Energy Frontier Research in Extreme Environments at GL.

The great potential of this program was recognized by the science directorate of the SNS, which established a formal relationship with GL. The relationship was cemented by the opening of a center for high-pressure science in the newly opened Joint Institute for Neutron Sciences

## Geophysical Laboratory, *Continued*

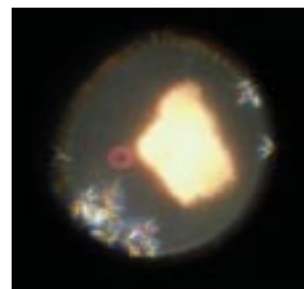
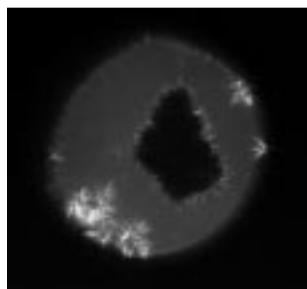
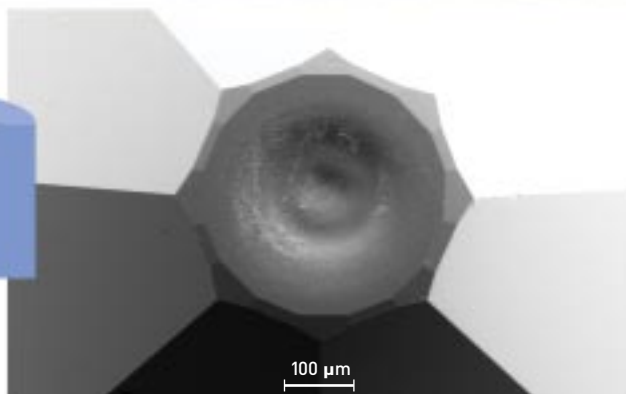


The decades-old tradition of neutron science at Oak Ridge National Laboratory (ORNL) has been catapulted toward new frontiers by the opening of the \$1.4 billion Spallation Neutron Source (SNS) facility (top left, image courtesy ORNL). Using a completely new generation of liquid-mercury targets, the SNS is able to generate neutron fluxes greatly in excess of any other neutron scattering source in the world. Inserts: The new Joint Institute for Neutron Sciences building (top middle), the high-pressure beamline at the SNS, which GL scientists help design and build (top right). Malcolm Guthrie (top) and Reinhard Boehler are aligning a cell.



New high-pressure devices for neutron diffraction experiments (above) allow large forces on large samples. This new geometry provides the necessary high diffraction angles. The sample volume is increased by ablating the diamond anvil tip with an excimer laser (right). These diamond anvil cells will allow neutron diffraction experiments on samples heated by a laser to several thousand degrees.

*Image courtesy Reinhard Boehler*



building. The SNS provides office and laboratory space and a generous investment in equipment, while operations are conducted by Carnegie staff.

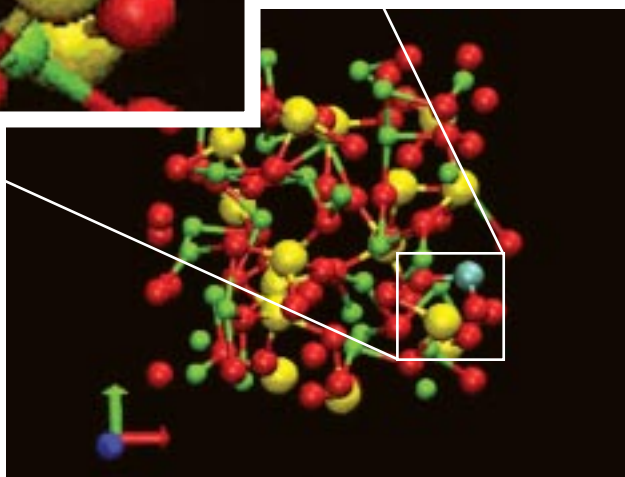
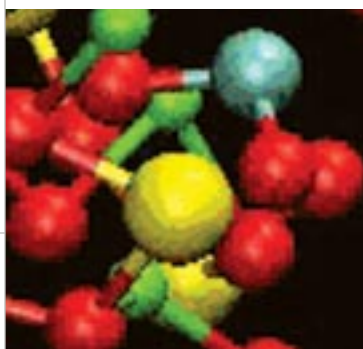
The endeavor's success depends on the development of novel high-pressure devices tailored for the neutron environment. Reini Boehler is leading this effort, building on the long-standing expertise in extreme-conditions technology at GL. The need for state-of-the-art materials and fabrication techniques maps directly onto existing programs in diamond growth and laser machining.

The very high SNS neutron flux will allow the use of drastically smaller samples than are customary in neutron diffraction studies, and an increase in the pressure range of neutron diffraction experiments. Because these samples are still larger than those in conventional X-ray diamond cell experiments, novel techniques are being developed. For increased anvil strength, the anvil geometry has been completely reconfigured, avoiding the necessity for very large, expensive anvils. Furthermore, the sample size is

increased by modifying the anvil shape by ion beam milling or UV laser ablation. A high-power laser will be used to heat these large samples uniformly to several thousand degrees.

## From Electrons to Planets

The ability to compute properties of atoms, molecules, crystals, and fluids from fundamental physics is flourishing because of advances in computing. Ronald Cohen and team harness this computer power to understand the behavior of minerals and fluids in the Earth and to design new materials. Simulating the behavior of electrons



(Above) This image is a frame from a movie simulating carbonated melts at roughly 1.3 million times atmospheric pressure (130 gigapascals) and 4900°F (3000 K). The blue is a carbon atom, red is oxygen, yellow is magnesium, and green is silicon.

*Image courtesy Razvan Caracas*

(Left) The Geophysical Laboratory's Ronald Cohen

*Image courtesy Ronald Cohen*

with quantum mechanics can reveal properties of minerals, rocks, and even planets.

Two exciting computational capabilities have emerged. One is the ability to simulate large systems as well as dynamical processes in time and at different temperatures. The other is improvements in the accuracy of first-principles methods, especially in systems where conventional methods fail. First-principles methods use only fundamental physics to predict molecular and material

properties, without the input of experimental data.

The simulations of large systems use high-performance computers and modern computer codes. For example, with former Carnegie Fellow Razvan Caracas, Cohen is using the QBOX code developed by François Gygi at U.C. Davis to simulate carbonated silicate melts in order to understand how carbon dissolves in the melt and how the melt changes with pressure. These calculations enable Cohen to unravel carbon transport in the Earth and to understand the partial melting of subducted slabs in the Earth's mantle.

Using Quantum Monte Carlo simulations—a more exact numerical solution of the Schrödinger equation—former Carnegie postdoctoral associate Ken Esler, Cohen, and others developed an accurate fundamental pressure scale for ultra-high-pressure experiments. Standard theory predicts that iron oxide (FeO) is a metal, but experiments show that it is an insulator. Some models predict it is an insulator, but those models predict different behavior than is observed under pressure. The researchers consider the problem using the Quantum Monte Carlo method and dynamical mean field theory, which includes the dynamical quantum fluctuations from electrons hopping among orbits. Preliminary results suggest that FeO may become metallic at high temperatures, such as those found in the Earth. In the Earth, FeO mixes with magnesium oxide making ferropericlase, Earth's second most common mineral.

The critical question for the researchers is how metalization depends on composition, pressure, strain, and temperature. Using these powerful tools, Cohen is teasing out a theoretical understanding of these complex materials and is able to confirm his predictions with experimental results by GL colleagues, including Viktor Struzhkin and Yingwei Fei. □

# Global Ecology

## *Linking Ecosystem Processes with Large-scale Impacts*



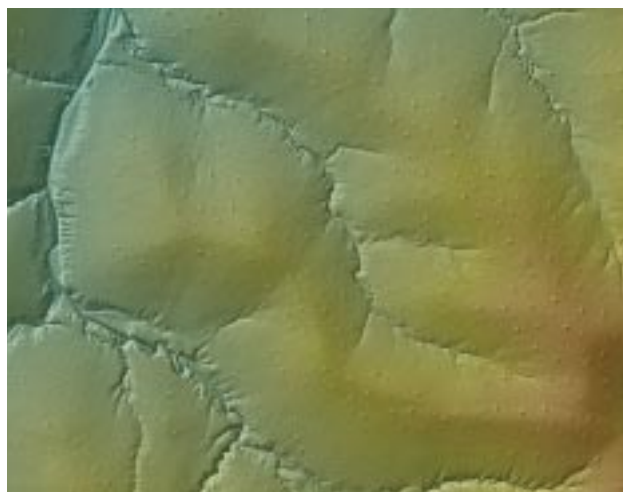
### Termites, Big Game, and Fire

Some surprising results about termites, fire, and wildlife browsing in the African savanna are coming out of Greg Asner's lab courtesy the Carnegie Airborne Observatory (CAO). The CAO is a unique airborne mapping system that penetrates the vegetation canopy to map the 3-D structure of the plants. Led by Asner, Shaun Levick and team are using it to reveal how termite mounds, large-animal browsing, and fire affect the vegetation structure and thus the savanna's ecology. The research could revolutionize land management and conservation.

The CAO uses a light detection and ranging (LiDAR) system to map the three-dimensional structure of vegetation. It combines that information with high-fidelity spectroscopic imaging to reveal the chemical fingerprints of the species below, and then renders the data in spectacular 3-D maps. The team conducted a number of different studies in the Kruger National Park in South Africa. They looked at the relationship of termite mounds to vegetation patterns, how the distribution of termite mounds affects browsing by large herbivores, the differences between fire and browsing impacts on the vegetation structure, and how herbivores affect the structural diversity of African savannas.

The CAO revealed that mound-building termites construct their nests in well-drained areas and on the slopes of savanna hills. Woody trees prefer the well-drained upslope side, while grasses dominate the wetter areas downslope. The scientists found that precipitation, elevation, and hydrological and soil conditions determine whether grasses or woody vegetation dominate and that different sizes and densities of termite mounds correlate with these environmental conditions. The spatial distribution of termite mounds is an excellent indicator of hill-slope water properties, thereby providing a unique avenue for monitoring vegetation changes in a changing climate.

In addition, termite mounds create fertile foraging "hotspots." The researchers compared browsed areas with protected areas to see if the mounds were correlated with foraging behavior. They found that animals prefer to consume the higher-quality woody plants at and near



The little dots on this LiDAR map are termite mounds distributed over the African savanna.

## Global Ecology, *Continued*

34

Global Ecology



(Left) A team of researchers approaches a termite mound surrounded by grasses and woody vegetation in the African savanna.

(Above) Large herbivores, such as this elephant, prefer to eat higher-quality woody vegetation at and near termite mounds.

*Images courtesy Shaun Levick*

the mounds and that the difference in vegetation structure between protected and unprotected areas was greatest for plants taller than 9 feet (3 meters), indicating that elephants favor tall plants.

The group also looked at the relative influence of fire and browsing on the vegetation. They found that browsing had a greater influence than fire. Their work is the first to be able to explicitly quantify the extent to which herbivores affect vegetation diversity.

## Farming Advances Versus Carbon Emissions

The Green Revolution, which took place in the second half of the 20th century, allowed developing nations to improve agricultural production through the use of pesti-

cides, fertilizers, and high-yield crops, as well as through access to machinery and improved irrigation techniques. This helped feed an expanding global population, but issues such as chemical runoff and water diversion have made the environmental impact of the revolution unclear. New research from Carnegie scientist Steven Davis, along with researchers from Stanford University, shows that since 1961 the high crop yields resulting from the Green Revolution have prevented the release of up to 161 gigatons of carbon dioxide into the atmosphere.

Agriculture is a major source of greenhouse gases. Emissions are caused by the conversion of natural areas into farmland, as well as by fertilizers, livestock, and fires, among other factors. Davis and his co-researchers investigated the effect that the advanced farming techniques promoted during the Green Revolution had on greenhouse gas emissions from 1961 through 2005.

The research team created two theoretical alternative scenarios for what actually happened agriculturally during that period. One alternative assumed that while the world's population increased and standards of living improved just as they did in the real world, agricultural technology remained at 1961 levels. The second alternative assumed that farm production only increased enough to maintain a 1961 standard of living through 2005.

In both scenarios, the use of fertilizers would have been much lower than is observed today. However, feeding the world without the use of advanced techniques would have required converting vast swaths of natural areas such as forests and scrubland to farmland, which would have drastically increased greenhouse gas emissions. These findings challenge the idea that industrial agriculture, with its use of pesticides and fertilizers, is worse for the environment than the old-fashioned way of farming.

The team also looked at the cost-effectiveness of agricultural research on reducing greenhouse gas emissions. They found that research is one of the cheapest ways of preventing greenhouse gas emissions, particularly compared with improvements in energy efficiency or transportation. What's more, the team says this research shows that efforts to increase agricultural yields are crucial to preventing the conversion of natural areas into farmland going forward, particular in carbon-rich tropical forests.

## Road to REDD

Until the Asner team recently developed a new high-resolution 3-D mapping system, there was no way to reliably measure carbon locked up in tropical forest vegetation and emitted by land-use practices—a prerequisite for accurate monitoring of carbon storage and emissions for



Old-fashioned farming does use fewer pesticides and less fossil-fuel-burning technology than modern agriculture, but feeding the world using old techniques would require converting large swaths of forests, scrubland, and other natural areas to farmland. As a result, feeding the world's population using old-fashioned farming techniques would actually emit more greenhouse gases than agriculture using modern techniques. The picture above shows hooded sprayers directing herbicide between rows of grain sorghum.

*Image courtesy Jack Dykinga and the U.S. Department of Agriculture*

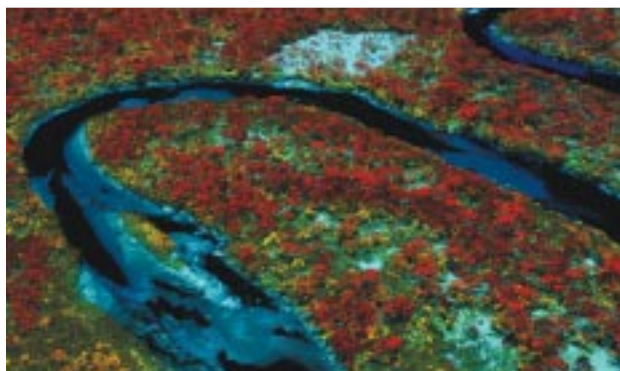
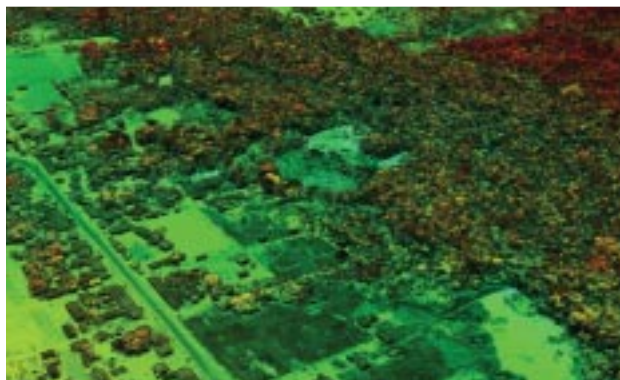


Global Ecology's  
Steve Davis

the new United Nations initiative on Reduced Emissions from Deforestation and Degradation (REDD).

REDD is designed to create financial incentives to reduce carbon emissions from deforestation and degradation so farmers and others in developing countries can be compensated for good climate practices. But carbon monitoring programs have been hindered by a lack of accurate, high-resolution methods.

Asner lab scientists, with colleagues, married satellite mapping, airborne-laser technology, and ground-based plot surveys to yield the first large-area, high-resolution maps of carbon locked up in tropical forest vegetation and emitted by land-use practices. The Asner team also



The colors in these images represent the height above ground in the Peruvian tropical forest. Blue is the ground level. Red areas are the tallest structures. Secondary and/or degraded forests are in greens and yellows; intact forest is red.

(Top) Roads and dwellings dominate the left side of this image in green. The farther away from habitation, the less destruction there is to the forests (red, upper right). (Center) The river (dark blue) dominates this image. (Bottom) The road shown in this image is the highly destructive Inter-oceanic Highway. Degraded areas appear in light blue; intact trees are red.

*Images courtesy Greg Asner*

developed new software for accessing this information so that governments, nongovernmental organizations, and academic institutions can monitor forests.

Their mapping study covered over 16,600 square miles of the Peruvian Amazon—an area about the size of Switzerland. The researchers mapped vegetation types and disturbance by satellite; developed maps of 3-D vegetation structure using a LiDAR system (light detection and ranging) from the Carnegie Airborne Observatory; converted the data into carbon density using a small network of field plots on the ground; and integrated the data to produce high-resolution maps. They combined historical deforestation and degradation data with 2009 carbon stock information to calculate emissions from 1999 to 2009 for the Madre de Dios region.

They found that the total regional forest carbon storage was about 395 million metric tons and that emissions reached about 630,000 metric tons per year. They were surprised by how carbon storage differed depending on forest types and underlying geology, finding important interactions among geology, land use, and emissions—the first such patterns from the Amazon.

Their software package, called CLASlite, automatically identifies deforestation and forest degradation from the satellite imagery, so the detailed maps can be easily searched for problem areas. Carnegie is teaming up with Google.org to provide “CLASlite Online” via Google’s Earth Engine, which greatly extends the ability of users to monitor their forests. The method will have a major impact on the implementation of REDD in tropical regions around the world.

□

# Observatories

*Investigating the Birth, Structure, and Fate of the Universe*



## Planet Hunting Just Got Better

A collaborative effort between Terrestrial Magnetism's Paul Butler and researchers at the Observatories has created one of the most precise tools for planet hunting in the world. It began in 2004, when then-research associate Jeff Crane joined Steve Shectman, Ian Thompson, and the Observatories team to design the Planet Finder Spectrograph (PFS), now installed and operational on the Magellan Clay telescope.

Radial velocities are the speeds and directions of stars moving away from or toward the Earth. Butler and team use them to detect the telltale wobbles of stars that are gravitationally tugged by orbiting planets. Astronomical spectrographs take collected light from a telescope and disperse it, splitting it into a spectrum of wavelengths. Elements in stellar atmospheres absorb light at specific wavelengths, creating narrow absorption lines in the spectra. The instrument measures shifts in these lines that are caused by changes in the star's motion. Astronomers observe velocity trends and infer planet orbital masses and other parameters. The necessary precision to detect small planets like Earth is very difficult to achieve.

The original goal for the PFS was to measure velocities to within 1 meter per second, currently considered state-of-

the-art. Although velocity measurements precise to 3 meters per second had been demonstrated by Butler by the late 1990s, only one other instrument in the world had achieved 1-meter-per-second precision prior to 2010. Results from the PFS have exceeded expectations. The velocity precision may be as good as 66 centimeters per second, making this instrument a superb planet-hunting machine.

To calibrate the data, the team uses a wavelength reference developed by Butler and collaborators. The starlight collected by the telescope passes through a glass cylinder containing molecular iodine gas. The iodine absorbs light

This photograph shows the Planet Finder Spectrograph on the instrument platform with part of the 6.5-meter-diameter Magellan Clay telescope (blue circular component) behind it. The unique thermal enclosure (white exterior with black interior) is temporarily open on one side.

*Image courtesy Jeff Crane*



## Observatories, *Continued*

38

Observatories

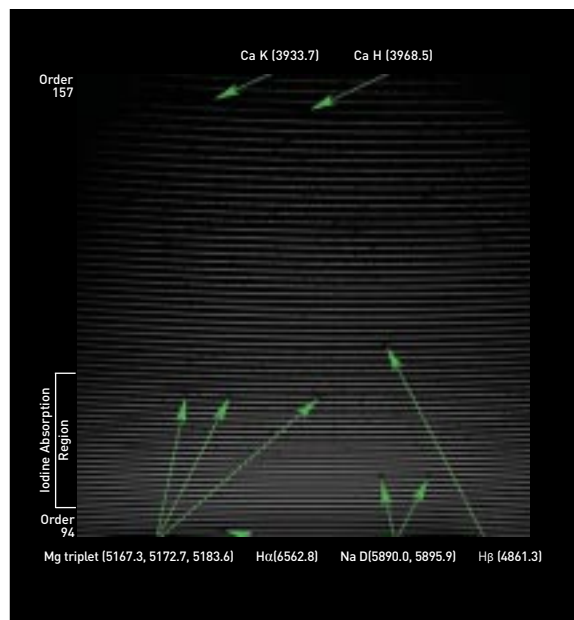


Observatories staff associate Jeff Crane modifies the instrument's control electronics enclosure to accept a new component.

*Image courtesy Paul Butler*

at specific wavelengths. The iodine spectra—the wavelength reference—are superimposed on the stellar spectra to help establish the velocity shift of the moving star. The iodine lines also help calibrate certain atmospheric and instrumental effects.

The PFS is exceptionally stable. The instrument is in a unique thermally controlled enclosure that keeps it near 77°F, regardless of the outside temperature, stabilizing the spectra constant over time. Shectman's optical design has yielded superior image quality, and the spectra are widely spread out so that fine features can be measured more easily.

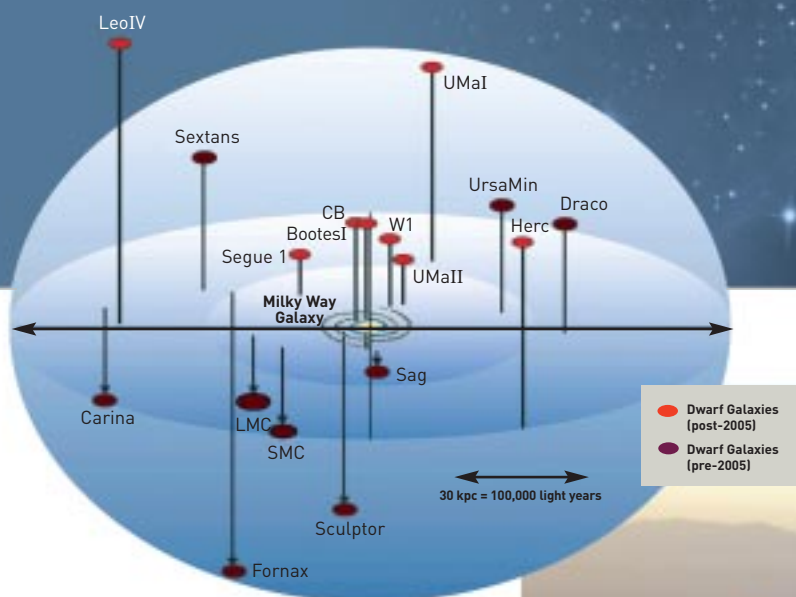


This spectral image was taken by the Planet Finder Spectrograph. Several chemical absorption line signatures are indicated by the green arrows.

*Image courtesy Jeff Crane*

## The Darkest Galaxy Known

Some galaxies are so dark they glow with the light of just a few hundred Suns. Josh Simon and colleagues have determined that a tiny, very dim galaxy orbiting the Milky Way, called Segue 1, is the darkest galaxy ever found and has the highest dark matter density currently known. His team has also laid to rest a debate about whether Segue 1 really is a galaxy or a globular cluster—a smaller group of stars that lacks dark matter. Their findings make Segue 1 a promising laboratory to study dark matter, particularly the possibility that dark matter



Dwarf galaxies neighboring the Milky Way are depicted in this diagram. Segue 1 is the darkest and densest galaxy discovered so far.

*Image courtesy Marla Geha*

Josh Simon (right) is at Carnegie's Las Campanas Observatory.

*Image courtesy Wendy Simon*



can be seen by the detection of gamma rays emanating from colliding dark matter particles.

Dark matter is the mysterious nonluminous material that makes up about 25% of the universe. Nearby dwarf galaxies have the highest measured densities of dark matter, making them ideal for dark matter studies, but that proximity also has a downside. Star systems so close to the massive Milky Way are subject to the acceleration of their stars by our galaxy's tidal forces, an effect that can mimic the presence of dark matter. The lack of bright stars in dim dwarfs also makes it difficult to measure the velocities of enough stars for sufficient certainty. Simon and company overcame these hurdles with a comprehensive program that measured and analyzed the speed and chemistry of 393 stars in the vicinity of Segue 1.

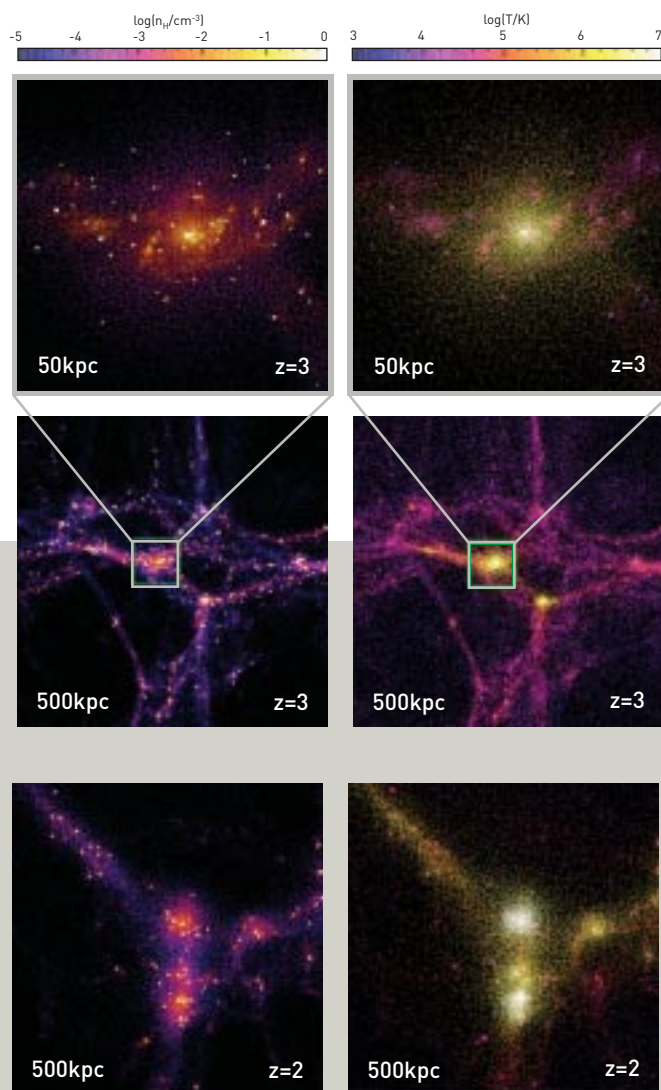
A major difference between galaxies and globular clusters is that the stars in galaxies contain widely varying

amounts of iron and other heavy elements, while stars in clusters do not. The new observations revealed that some Segue 1 stars have 50 times less iron than other Segue 1 stars, demonstrating conclusively that Segue 1 cannot be a globular cluster.

In collaboration with astronomers at the University of California, Irvine, Simon also showed that the high speeds of the Segue 1 stars are not caused by invisible binary companion stars, firming up the estimates of the amount of dark matter in the galaxy. Ongoing observations with NASA's Fermi Gamma-ray Space Telescope are searching for signals from Segue 1 and other dwarfs, which would provide astronomers with concrete proof that their dark matter theories are on the right track.

Observatories, *Continued*

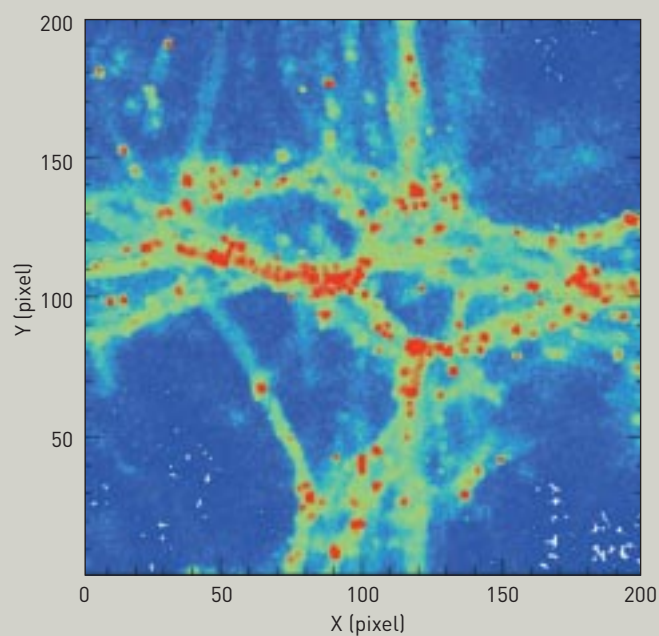
Juna Kollmeier



(Left) This simulation at 2.2 billion years after the Big Bang is for an area that is approximately 4.9 million light-years on a side. The left figures show the gas density and the right show the temperature. The top images are blowups of the central patch in the middle images. They reveal a single galaxy system at the intersection of multiple gas filaments shown at bottom.

(Below) The image simulates the area of multiple gas filaments from the images at left through Lyman-alpha "eyes."

(Below right) The figure on the right shows what an observer would see with the current generation of telescopes after many hours of integration. It includes foreground noise. Each red dot corresponds to the gaseous regions surrounding simulated galaxies. Kollmeier can compare the simulated images with images obtained by real telescopes and see if her theoretical models are correct.



## Unraveling the Cosmic Web

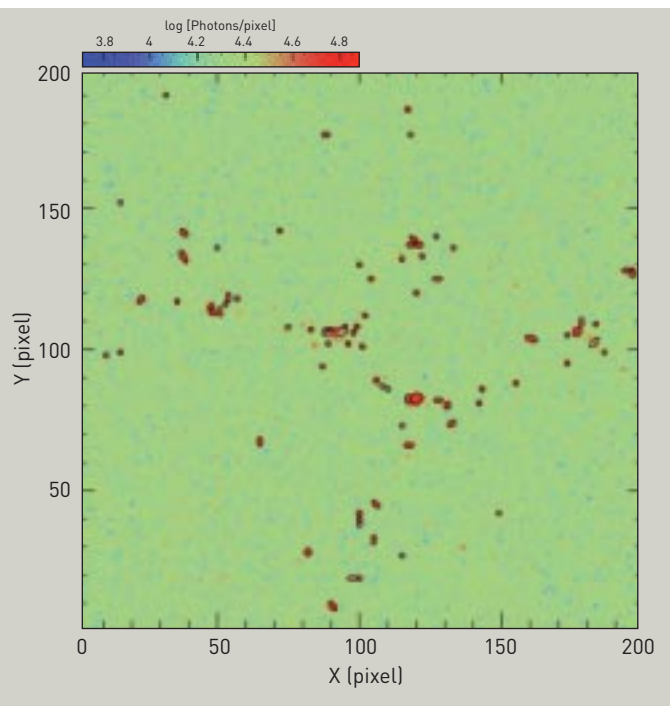
The universe is mayhem. Gravity drags galaxies toward each other, while dark energy pushes them apart. Stars explode as supernovae, ejecting elements and gas, while at the same time enormous filaments resupply material for star formation. Stars are born and stars die. Although visually stunning, the universe is messy. Juna Kollmeier is unraveling the chaos of structure formation by combining state-of-the-art cosmological hydrodynamic simulations with astronomical observations of the Intergalactic

Medium (IGM). The results are beautiful images showing what the universe once was.

The IGM is the directly observable material that resides between galaxies; it is mostly hydrogen and can be traced by measuring that gas. The IGM is the best-understood component of the currently favored cosmological model of the universe. It is a source for galaxy formation and a sink for its by-products—photons, heavy elements, and kinetic energy. It also reveals the underlying distribution of dark matter—the unobservable material that is more abundant than ordinary matter and is crucial to galaxy formation. These features make the IGM ideal for studying the complex processes of galaxy formation and evolution.

Kollmeier looks at the chemical fingerprints revealed by analyzing light as it passes through the IGM. Each element absorbs or emits light at specific wavelengths, producing unique absorption or emission patterns. One-dimensional absorption studies have been around for a long time. But the future lies with three-dimensional emission-line mapping of the IGM, which will provide a critical new picture of structure formation. Kollmeier has taken the lead in producing predictions for 3-D emission-line maps of the young universe.

Using spectral observations to test cosmological models requires accurate predictions of the emission signature from the IGM. Kollmeier has developed software that makes these predictions possible. She performs radiative transfer calculations of Lyman-alpha photons—the photons that trace the state of intergalactic material as energy from stars and quasars gets reprocessed by the intergalactic gas. Kollmeier's combination of software and computing power provides necessary tools to make accurate predictions that address the most fundamental questions about how galaxies get their fuel and use it over their life cycle. □



# Plant Biology

## *Characterizing the Genes of Plant Growth and Development*



### Adapting by Computing

In the wake of epic floods and fires, are famines on the horizon? Many say yes and are looking at ways to adapt to climate change. One way may be through faster identification and manipulation of crop genes to resist or tolerate environmental extremes. Sue Rhee and team created a new computational model, called AraNet, to predict the function of uncharacterized plant genes with unprecedented speed and accuracy. She, with colleagues, used it to predict a drought-related function of one previously uncharacterized gene and confirmed with follow-up experiments that it is involved in the drought response.

AraNet encompasses over 19,600 genes of the tiny, experimental mustard plant *Arabidopsis thaliana*, which are associated to each other by over 1 million links. AraNet can increase the discovery rate of new genes affiliated with a trait tenfold. It is based on the notion that genes near each other, or that turn on in concert with one another, are probably associated with similar traits. The model is based on the evidence gathered from some 50 million scientific observations, which enables the map of associations to be made. Researchers propose that uncharacterized genes are linked to specific traits based on the strength of their associations with genes already

known to be linked to those characteristics. They then follow up with experiments that suppress the activity of the uncharacterized gene to see what normal characteristics in the plant go awry.

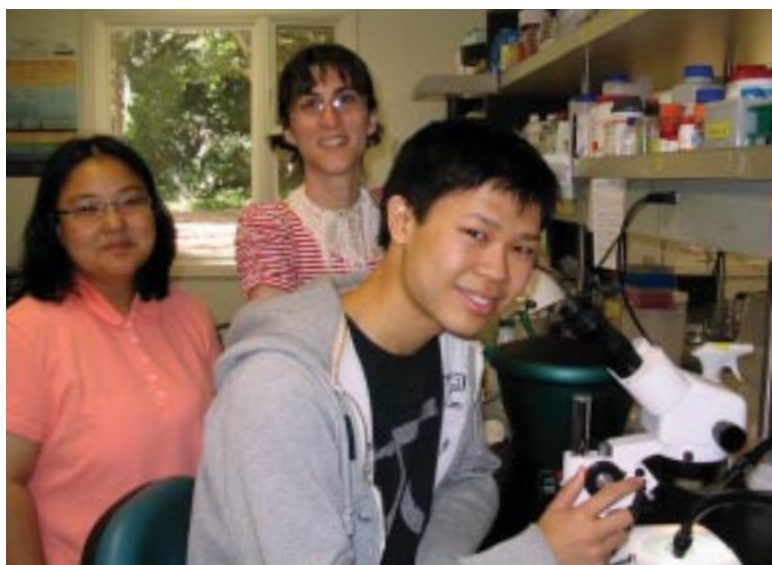
AraNet suggested that a gene called *AT1G80710* could be involved in the response to water deprivation. The researchers found that under drought conditions mutant plants lacking this gene held in only 80% of the water that normal plants did; they were “blind” to drought.

The plant hormone abscisic acid (ABA) controls numerous physiological processes, including responses to stresses. It is also part of a molecular relay that mediates drought response by keeping water loss in check. The researchers looked to see if response to ABA was affected in the mutant plant by examining the effect of the hormone on transpiration—the process of “exhaling” water vapor from leaves to the atmosphere. Transpiration in the mutant was not affected by the hormone, with the result that the mutant lost significantly more water than the normal plants. The experiments confirmed what AraNet identified—that the gene is involved in sensing drought. The group renamed the gene *DROUGHT SENSITIVE 1* (*DRS 1*).

### Watching Molecular Scaffolds Take Shape

For the first time scientists have witnessed how proteins common to both plants and animals build specialized molecular scaffolds that are essential for creating the shapes of plant cells. The study, by David Ehrhardt and Takashi Hashimoto, is important in advancing cell biology research and crop engineering.

Plants, animals, and fungi all use hollow protein rods called microtubules to support cell shape, movement, and

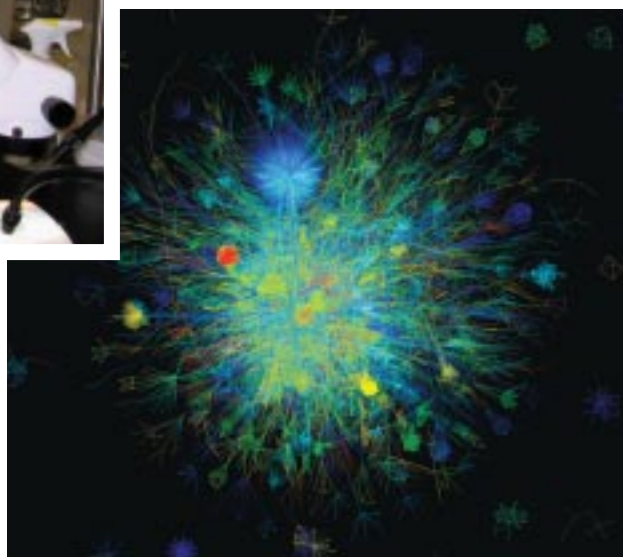


(Above) Team members working on Rhee's research into the mechanisms of the drought response are (left to right) Hye-In Nam, Flavia Bossi, and Nathaniel Leu.

*Image courtesy Sue Rhee*

(Right) The AraNet model contains some 50 million scientific observations, from which a map of associations is made. Each line of this network represents a functional link between two genes. The colors indicate the strength of the link using a red-blue heat map scheme.

*Image courtesy Insuk Lee of Yonsei University*



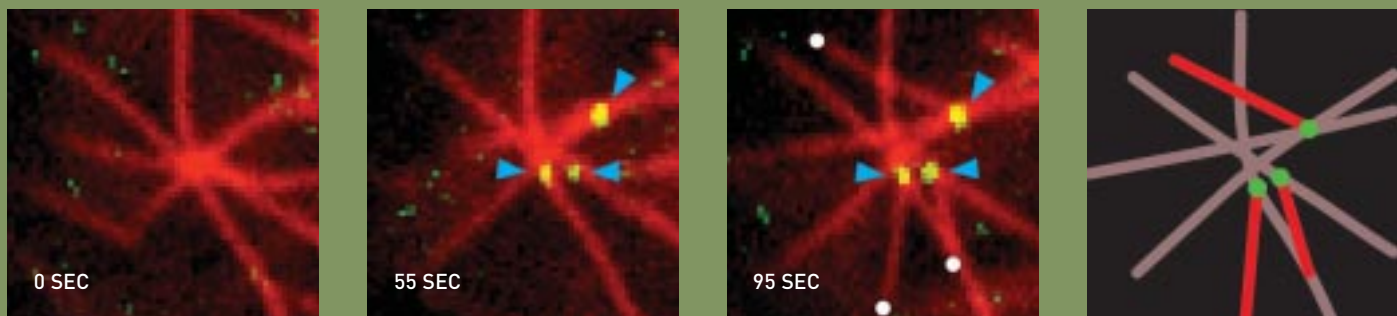
division. These rods are arranged in a specific configuration, a molecular scaffolding, which organizes other proteins and cell processes. Much has been discovered about how microtubules are arranged from a central hub in animal cells known as a centrosome. However, microtubules can be arranged in configurations that do not utilize a central hub. How these other configurations are created has remained a mystery. Plant cells are appropriate for studying this problem because they lack centrosomes.

An essential function of the centrosomal hub is to serve as a platform for nucleating complexes, proteins that give birth to new microtubules. To determine where these nucleating complexes are and how they function in plant cells, the Ehrhardt and Hashimoto team tagged them with a jellyfish fluorescent protein and introduced them into plant cells.

They saw that most nucleating complexes are recruited to the sides of other microtubules and that new microtubules are much more likely to arise from these complexes than from those that are recruited to other locations. These observations suggest that the microtubules are important for locating and regulating their own formation proteins. The researchers also found that the molecular complexes formed newborn microtubules at two distinct orientations. The scientists believe that this orientation choice may play a role in organizing the microtubules.

In a previous study, the Ehrhardt lab discovered that new microtubules are separated from their sites of birth shortly after they are created, after which they migrate to new locations in the cell. The researchers speculated that this process was important for organizing the microtubules.

The scientists thought that a protein called katanin



The Ehrhardt lab previously found that the scaffolding that shapes plant cells, called microtubules, is born along the inside of the cell membrane. To visualize the birthing process, the team tagged molecular complexes that give rise to microtubules and observed the construction of the microtubule network. Red is tubulin, the protein that makes up the microtubules. Green is tagging the molecular complex (which appears yellow where it overlaps the tubulin). The time series shows the recruitment of molecular complexes to the sides of a microtubules (blue arrows) and the birth of new microtubules from the complexes (growing ends marked with white circles at 95 seconds). The diagram highlights the locations of the complexes and new microtubules.

*Images courtesy of Viktor Kirik and David Ehrhardt.*

might be responsible for the separation process, so they introduced their probes into a mutant plant lacking the katanin protein. Without katanin, the newborn microtubules failed to detach from the nucleating complex, and the complex remained in place. These results demonstrated that katanin is required for freeing new microtubules and liberating the nucleating complex so that it can be used in a new location.

## Cutting the Green

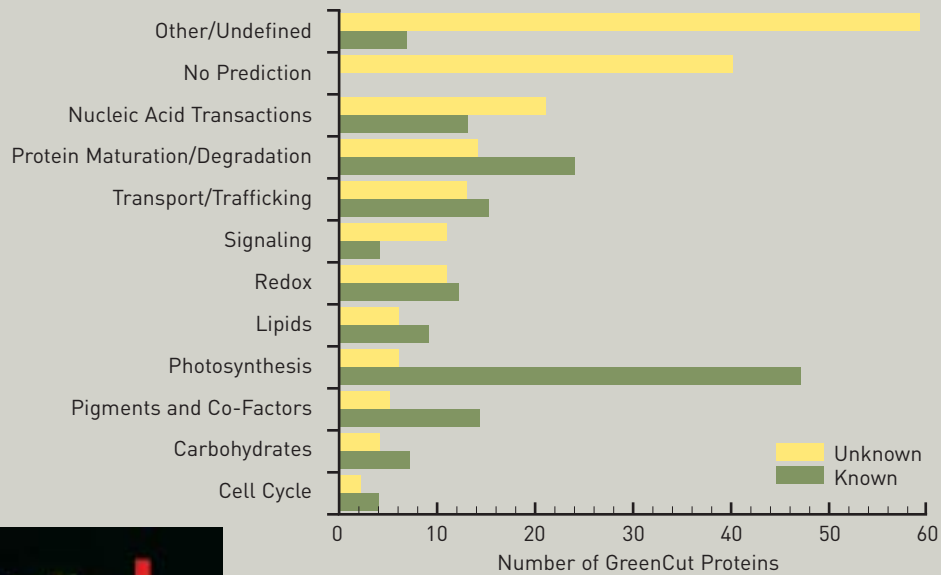
Although scientists have been able to sequence the genomes of many organisms, they still lack a context for identifying the biological processes to which these genes contribute. Furthermore, understanding how groups of genes are shaped by environmental forces, developmental processes, and transfer among species could give researchers important insights into key biological processes. To this end, Arthur Grossman and colleagues generated a list of proteins that are present in members of the plant kingdom and in green algae but not in non-photosynthetic organisms. Many of these proteins have no known biological function, but are localized to a cellular organelle called the chloroplast and have features that suggest a function in photosynthesis. The researchers hope to reveal the roles of the genes that encode these proteins in green-lineage organisms and learn how these genes might affect photosynthesis.

It is believed that chloroplasts originated as photosynthetic, single-celled bacteria (called cyanobacteria), which were engulfed by eukaryotic, nonphotosynthetic cells more than 1.5 billion years ago. While the relationship between the two organisms was originally symbiotic, over evolutionary time the bacterium lost its ability to live without its partner. It eventually turned into a chloroplast, the compartment in the cell that performs photosynthesis.

Using a variety of computational techniques, Grossman and colleagues at UCLA and the Joint Genome Institute were able to generate a list of 597 proteins specifically present in members of the plant kingdom and in green algae but not in nonphotosynthetic organisms. They named these proteins the GreenCut.

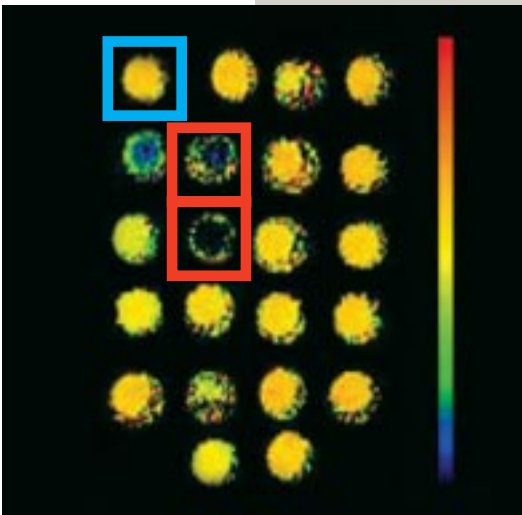
The biological functions of a large portion of the 597 GreenCut proteins are not known. However, the team has been able to narrow down potential activities for several by figuring out when and where they are expressed. Genetic and biochemical research is being performed to continue piecing together clues about GreenCut proteins that will reveal their roles in green-lineage organisms, especially how they might affect photosynthetic function.

Many GreenCut proteins are in red algae, other single-celled algae called diatoms, and ancient chlorophyll-containing cyanobacteria. Comparisons of GreenCut proteins in these organisms open a window for potential key discoveries about the evolution of chloroplasts and the roles they perform in photosynthetic cells. □



The bars along the y-axis represent the GreenCut proteins classified by function. The number of proteins in each functional classification is shown on the x-axis. Green bars represent proteins with known functions; yellow bars represent proteins of unknown function. Note that while the physiological functions of many proteins in the Photosynthesis and Pigments and Co-Factors sections are known, the functions of many proteins associated in the Signaling and Nucleic Acid Transactions categories are not.

*Images courtesy Arthur Grossman*



(Above) Strains of algae with mutations in genes encoding GreenCut proteins can have observable characteristics that indicate a defect in the use of the light energy necessary for photosynthesis. Fluorescence-emission tests indicate that some GreenCut-defective mutants have reduced activity in major photosynthetic protein complexes compared with nonmutant algae (blue box). The mutant strains in the red boxes show very low photosynthetic efficiency.

(Right) Plant Biology's Arthur Grossman

*Images courtesy Arthur Grossman*



# Terrestrial Magnetism

*Understanding Earth, Other Planets, and Their Place in the Cosmos*



## The Case of the Mysterious Volcanic Islands

A long-standing geological mystery, the origin of the volcanic Hawaiian Islands, could soon be solved. Plate tectonics explains the existence of volcanoes at boundaries where plates spread apart or collide, but midplate volcanoes, such as those that built the Hawaiian island chain, have been harder to fit into that theory.

New research carried out by Sean Solomon and Erik Hauri and led by former Department of Terrestrial Magnetism (DTM) postdoctoral fellow Cecily Wolfe (now at the University of Hawaii) lends support to one proposed explanation for the Hawaiian volcanoes. This nearly 40-year-old model suggests that magma is supplied to the volcanoes from upwellings of hot rock, called mantle plumes, which originate deep in the Earth's mantle.

Although evidence for these types of plumes has been sketchy in the past, two years' worth of data from seismometers placed both on land and on the seafloor have provided an unprecedented glimpse of the roots of the Hawaiian hot spot. This sophisticated array of seismometers was able to show the first high-resolution seismic images of a mantle plume extending to depths of at least 900 miles (1,500 kilometers).

The research project is known as PLUME, for Plume-Lithosphere Undersea Melt Experiment. The development of broadband seismic instruments capable of being set on the seafloor for long periods was integral to gathering these new data, since many of the major hot spots are in the oceans and far from major landmasses.

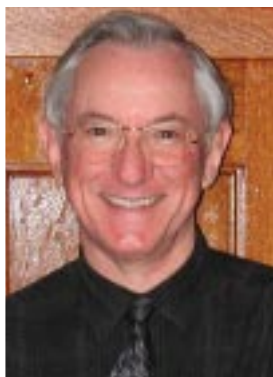
The seismic images show that the volume of low seismic velocities is approximately the size of the island of Hawaii, which is positioned near the center of the upper mantle portion of the velocity anomaly. These results match expectations from the plume model.

Critics of the plume explanation have argued that the magma in hot spot volcanoes comes from relatively shallow depths, not from deep upwellings. But the depth of the hot spot roots observed in this research lends strong support to the plume hypothesis.

Researchers retrieve an ocean-bottom seismometer in May 2007. The dangling silver sphere houses the actual seismic sensor; orange containers house the electronics and batteries.

*Image courtesy Gabi Laske, University of California, San Diego*

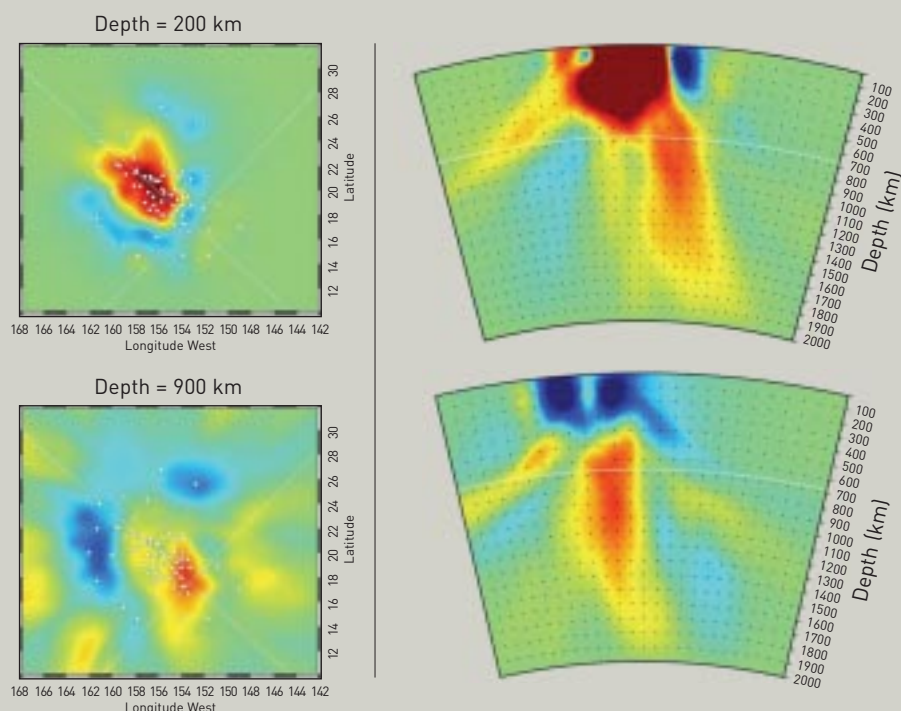




(Above) Sean Solomon is director of the Department of Terrestrial Magnetism.

(Right) These images show anomalous seismic velocities beneath the Hawaiian Islands. The orange and red colors indicate low S-wave velocities, which imply higher rock temperatures. The left two images are horizontal cross sections at depths of about 125 miles (200 kilometers) and nearly 560 miles (900 kilometers); boxes represent the locations of seismometers on the overlying seafloor. The right two images show vertical cross sections through the region. The upper of the two is oriented northwest to southeast, and the lower southwest to northeast.

Image from Science 326, 1388, 2009.  
Reprinted with permission from AAAS.



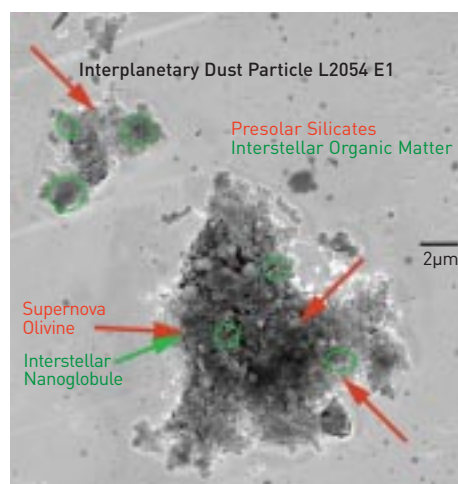
## Spaced-Out Dust

Particles floating in Earth's upper atmosphere generally come from space—not from the planet's surface—and can help scientists understand the Solar System's history. Collected using specialized NASA planes, these interplanetary dust particles, or IDPs, likely originated from comets and asteroids. Carnegie scientists Larry Nittler and George Cody, with former DTM postdoctoral fellows Henner Busemann (now at the University of Manchester) and Ann Nguyen (now at the Johnson Space Center) and colleagues from the U.S. Naval Research Laboratory, the

Lawrence Berkeley National Laboratory, and the Max Planck Institute for Chemistry in Germany, found that a few special IDPs came from the dust trail of a comet called Grigg-Skjellerup and entered our atmosphere as Earth passed through the comet's tail in 2003. This was the first time researchers could tie a single particle of dust found in Earth's stratosphere to a specific comet.

Comets, which come from the frigid outer reaches of the Solar System, are believed to be repositories of unaltered material left over from the system's formation. Their dust, protected from the heating and chemical processing that has affected other bodies such as asteroids

## Terrestrial Magnetism, *Continued*



(Left) Larry Nittler inspects the Stardust collection grid at the NASA Johnson Space Center. Interplanetary dust particles gathered by NASA's Stardust mission were compared with dust particles from the Grigg-Skjellerup comet gathered by Nittler's team.

*Image courtesy Larry Nittler*

(Above) This is a scanning electron image of interplanetary dust particles containing presolar silicate grains and interstellar organic matter.

*Image courtesy Henner Busemann*

and planets, provides scientists with a glimpse of some of the primitive matter that formed the Sun and the planets.

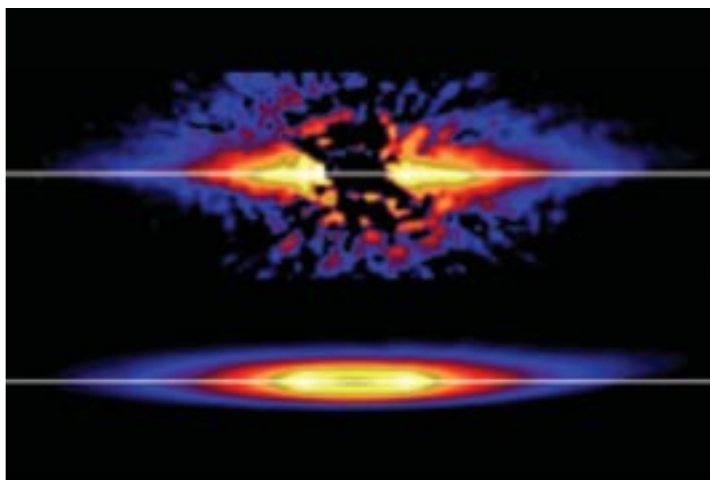
The stratospheric dust from Grigg-Skjellerup exhibited a number of ultraprimitive characteristics, notably a surprisingly high abundance of presolar grains—minute particles that likely formed inside stars that lived and died long before the Sun's birth. Presolar grains have much more unusual isotopic compositions than anything else in the Solar System. They are extremely rare in meteorites from the asteroid belt and even in most stratospheric IDPs, making their high concentration in Grigg-Skjellerup dust very exciting. The dust also showed an abundance of disordered organic matter with isotopic compositions that point to an origin in interstellar space.

The team compared the Grigg-Skjellerup dust with dust from a comet called 81P/Wild 2, which was collected in space by NASA's Stardust mission and returned to Earth in 2006. Scientists had expected that the Wild 2 dust would be primitive, but the samples included more altered mate-

rial than expected. The dust from the Grigg-Skjellerup comet was much more primitive than the Wild 2 dust. This result potentially indicates a vast diversity in the materials that make up comets, as well as in the degree of thermal and chemical processing that comets and dust have experienced in the eons since their formation.

## Supersonic Ballistic Drag

Alycia Weinberger's lab is light-years away. She probes the dusty disks surrounding nearby young stars—with their own cometary and asteroidal dust—for clues to how our own Solar System formed. Recently, she and her team made multicolor images of a disk around the star HD 32297, which is 365 light-years from the Sun—nearby as disks go. She wanted to learn about the composition of the disk to see what it could teach us about the primitive Solar System. Using the Hubble Space Telescope (HST),



(Left) Terrestrial Magnetism's Alycia Weinberger. (Right) The dusty disk observed around the star HD 32297. Weinberger's team found the density of gas in the Interstellar Medium (ISM) and collision velocity between the star and the ISM cloud that could reproduce the disk's shape. Although not obvious in the image, careful measurements show that starting about 150 astronomical units (AU) from the star (1 AU is the distance from the Earth to the Sun), one side of the disk is curved away from the star creating a warp. This model is presented in the lower panel.

(Left) Image courtesy Alycia Weinberger / (Right) Image courtesy Alycia Weinberger and The Astrophysical Journal

she looked for variations in composition within the disk.

Her team found a complicated color variation in a strangely shaped, warped disk. Former DTM postdoctoral fellow John Debes (now at NASA Goddard) developed a model of gas/grain interactions and showed that the shape probably came from the interactions between disk grains and hydrogen gas in the interstellar medium (ISM). The dust likely experiences supersonic ballistic drag as it hits the ISM gas—similar to what meteorites encounter when they enter Earth's atmosphere—warping the disk's shape. The ISM dust could also sandblast the outer parts of the disk, changing the sizes of the dust grains and their reflective colors.

The astronomers used the coronagraph in the near-infrared camera on the HST to block the light of the star so that disk grains scattering starlight would be visible. The color of the scattered light depends on the composition and size of the grains. Their observations probed parts of the disk comparable to the distance between our Sun and Neptune and beyond in our own system. The disk grains are gray in the innermost portion of the image—they scattered all three wavelengths equally. The color gray suggests large silicate grains perhaps coated with water ice. At the disk's warp, the researchers saw a

change to a bluer color, suggesting small and eroded grain remnants from collisions with the ISM.

The same processes at work for HD 32297 could have shaped our outer Solar System. For the young stars that Weinberger observes, the interaction of a disk and the ISM is pivotal to understanding the environment in which planets form. □



Weinberger and team use the Hubble Space Telescope for observing dusty disks around nearby stars. This image shows Hubble drifting over Earth in 2009.

Image courtesy NASA

# First Light & The Carnegie Academy

## *Teaching the Art of Teaching Science*



50

First Light &amp; The Carnegie Academy for Science Education

## DC STARS

The CASE DCBiotech Project and Carnegie's NASA Astrobiology Institute (NAI) team forged a new partnership—Student Teacher Astrobiology Researchers (STARS). Eleven Ballou Senior High School students and their teacher met the NAI team and learned firsthand about the variety of research expeditions to Svalbard, Norway, to prepare for the search for life elsewhere in the universe. During a two-week institute at the Carnegie labs, the STARS learned to apply methods used in the Arctic expeditions to design an expedition to Ballou to collect extremophiles—organisms that live in extreme conditions, such as in a hot water system and on rooftops. Scientists from Andrew Steele's laboratory advised the STARS researchers back at Ballou through computer-mediated videoconferencing. The students presented their findings at an August miniconference.

## Branching Out

DC Biotech has established biotechnology career pathways at Ballou and McKinley Technology high schools

in Washington. Now, with support from the Shippy Foundation and the Association of American Medical Colleges, students citywide will experience exciting biotech research through a new Lab Loaner Program. Middle and high school science teachers from the D.C. area, trained by CASE, can borrow four different teaching kits for two to three weeks. Each features a biotechnology lesson, complete with curriculum guides.

With support from the National Human Genome Research Institute DNA DAY Program, CASE introduces adults and children to the increasingly accessible world of online bioinformatics research through the simple yet elegant craft of beading bracelets. Four bead colors represent the four DNA bases. The jewelry models real DNA sequence information three ways: by randomly stringing 15 to 18 beads and looking up the DNA sequence on GenBank; by retrieving a selected gene's DNA sequence from GenBank, then beading a segment; or by using the genetic code to bead a secret DNA message.

## Going Global

For several years Carnegie has cohosted the Royal Embassy of Norway Transatlantic Science Week. Serendipity sparked a DC Biotech–Norwegian partnership with Ullern High School, Oslo University, and the Oslo Cancer Cluster. The partners visited each other's sites and are designing curricula for students to explore nutrition and diabetes, crime scene investigation, and genomics. Conducting collaborative research projects through videoconferences, the high school students will experience real-world international scientific teamwork while learning about biotechnology careers and each other's cultures. □

# for Science Education



(Top left) STARs students Juwana Douglas and Linda Jamison and teacher John Solano discuss the results of a sampling method they piloted during the two-week institute at Carnegie.

*Image courtesy Toby Horn*

(Below left) Children bead DNA bracelets at a local science festival. The CASE DNA DAY project sends kits upon request to high schools and community colleges around the country. Kits include beads in the schools' colors along with lessons, teaching PowerPoints, reference materials such as genetic code sheets, and a "Budding Bioinformatician" Certificate of Participation.

*Images courtesy Toby Horn*



(Above) DCBiotech members went to Oslo, Norway, in May 2010, to visit their Norwegian biotech partners. Members from the U.S. include Marti Jett (in blue jacket, standing on left) and Debra Yourick (sitting second from right) of the Walter Reed Army Institute of Research. They were joined by Ballou teacher John Solano (crouching, right), McKinley teacher Joseph Isaac (standing, right), and J. Craig Venter Institute partner Lisa McDonald (next to Isaac). The Oslo Cancer Cluster and the Royal Norwegian Embassy sponsored CASE codirector Toby Horn (front) and the teachers from the D.C. Public Schools.

# Financial Profile

*for the year ending June 30, 2010 (unaudited)*

**Reader's Note:** *In this section, we present summary financial information that is unaudited. Each year the Carnegie Institution, through the Audit committee of its Board of Trustees, engages an independent auditor to express an opinion about the financial statements and the financial position of the institution. The complete audited financial statements are made available on the institution's website at [www.CarnegieScience.edu](http://www.CarnegieScience.edu).*

The Carnegie Institution of Washington completed fiscal year 2010 in sound financial condition due to the positive returns (+11.0%) of the diversified investments within its endowment; a disciplined spending policy that balances today's needs with the long-term requirements of the institution and the interests of future scientists; and the continued support of organizations and individuals who recognize the value of nurturing basic science.

The single primary source of support for the institution's activities continues to be its endowment. This reliance on institutional funding provides an important degree of independence in the research activities of the institution's scientists.

Carnegie, like many institutions of higher education and nonprofit organizations, experienced a challenging period financially during fiscal year 2009, when our endowment declined by approximately 27% in value. As a result, over the last two fiscal years Carnegie has had to reduce its expenses while simultaneously ensuring the continuation of a healthy scientific enterprise. During fiscal year 2010, the endowment rebounded partially and grew from \$636.4 million to \$692.0 million.

Even when taking into account the precipitous decline in 2009, the endowment's value over the last eleven years has grown from \$478 million to approximately \$692 million as of June 30, 2010. As a result, over the period 2001-2010, average annual increases in endowment contributions to the budget were 5.6%.

Carnegie refinanced the institution's debt in fiscal year 2010 to take advantage of attractive fixed long-term interest rates. During that process, Carnegie's long-term financial strength was reaffirmed by Moody's Investors Service and Standard & Poor's. These rating agencies reviewed Carnegie's financial position and gave the institution their highest and second highest rankings, respectively, a level achieved by only a few nonprofit organizations.

For a number of years, under the direction of the Finance committee of the board, Carnegie's endowment has been allocated among a broad spectrum of asset classes including: fixed-income instruments (bonds), equities (stocks), absolute return investments, real estate partnerships, private equity, and natural resources partnerships. The goal of this diversified approach is to generate attractive overall performance and minimize the volatility that would exist in a less diversified portfolio.

The Finance committee of the board regularly examines the asset allocation of the endowment and readjusts the allocation, as appropriate. The institution relies upon external managers and partnerships to conduct the investment activities, and it employs a commercial bank to maintain custody. The following chart shows the allocation of the institution's endowment among asset classes as of June 30, 2010.

Asset Class	Target	Actual
Common Stock	37.5%	36.1%
Alternative Assets	55.0%	54.1%
Fixed Income and Cash	7.5%	9.8%

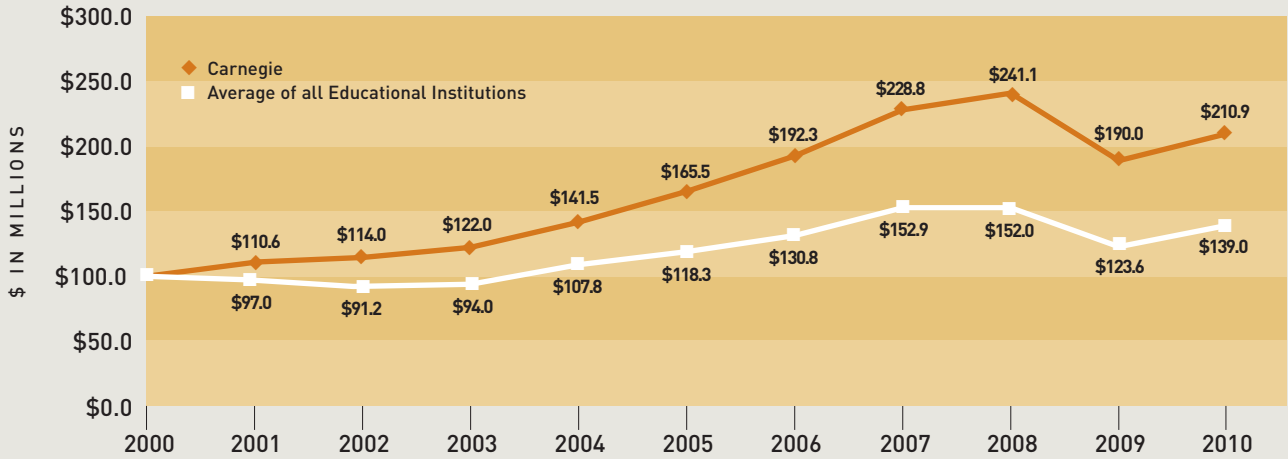
Carnegie's investment goals are to provide high levels of current support to the institution and to maintain the long-term spending power of its endowment. The success of Carnegie's investment strategy is illustrated in the following figure that compares, for a hypothetical investment of \$100 million, Carnegie's investment returns with the average returns for all educational institutions for the last eleven years.

Carnegie has pursued a long-term policy of controlling its spending rate, bringing the budgeted rate down in a gradual fashion from 6+ % in 1992 to 5.00% today. Carnegie employs what is known as a 70/30 hybrid spending rule. That is, the amounts available from the endowment in any year is made up of 70% of the previous year's budget, adjusted for inflation, and 30% of the most recently completed year-end endowment value, multiplied by the spending rate of 5.0% and adjusted for inflation and for debt. This method reduces volatility from year-to-year. The figure shown at right (bottom) depicts actual spending as a percentage of ending market value for the last 19 years.

In fiscal year 2010, Carnegie benefitted from continuing increases in federal support. Carnegie's federal support has grown from \$24.5 million in 2006 to more than \$36 million in new grants in 2010. This is a testament to the high quality of Carnegie scientists and their ability to compete successfully for federal funds.

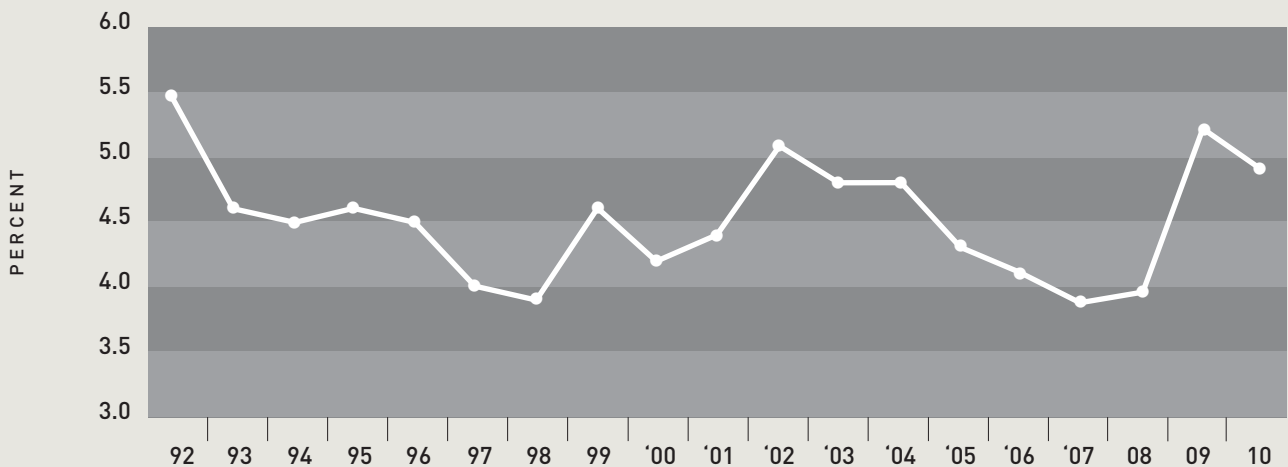
Carnegie also benefits from generous support from foundations and individuals. Funding from foundations has grown from an average of about \$3 million/year in the period from 2000 to 2004 to between \$5 and 6 million/year from 2006 to 2010. Within Carnegie's endowment, there are a number of "funds" that provide support either in a general way or targeted to a specific purpose. The largest of these is the Andrew Carnegie Fund, begun with the original gift of \$10 million. Mr. Carnegie later made additional gifts totaling another \$12 million during his lifetime. This tradition of generous support for Carnegie's scientific mission has continued throughout our history, and a list of donors in fiscal year 2010 appears in an earlier section of this yearbook. In addition, Carnegie receives important federal and private grants for specific research purposes, including support from the Howard Hughes Medical Institute for researchers at the Department of Embryology.

## Illustration of \$100 Million Investment - Carnegie Returns vs. Average Returns for All Educational Institutions (2000-2010)



Average returns for educational institutions are taken from Commonfund reports on endowment performance.

## Endowment Spending as a Percent of Ending Endowment Value\*



\*Includes debt financing.

**Statements of Financial Position (unaudited)**

June 30, 2010, and 2009

	2010	2009
<b>Assets</b>		
Current assets:		
Cash and cash equivalents	32,359,327	3,587,777
Accrued investment income	46,301	46,430
Contributions receivable	6,342,270	5,519,038
Accounts receivable and other assets	20,411,836	16,750,719
Bond proceeds held by Trustee	26,728	39
Total current assets	\$ 59,186,462	\$ 25,904,003
Noncurrent assets:		
Investments	688,251,697	633,525,475
Property and equipment, net	156,738,554	157,980,529
Total noncurrent assets	\$844,990,251	\$791,506,003
Total assets	\$904,176,713	\$817,410,006
<b>Liabilities and Net Assets</b>		
Accounts payable and accrued expenses	18,579,451	9,759,780
Amount held for others	33,186,239	—
Deferred revenues	33,916,916	40,746,194
Bonds payable	65,800,315	65,358,062
Accrued postretirement benefits	15,246,053	14,560,478
Total liabilities	\$166,728,974	\$130,424,514
Net assets		
Unrestricted	217,326,563	206,347,417
Temporarily restricted	465,231,580	425,774,379
Permanently restricted	54,889,596	54,863,696
Total net assets	\$737,447,739	\$686,985,492
Total liabilities and net assets	\$904,176,713	\$817,410,006

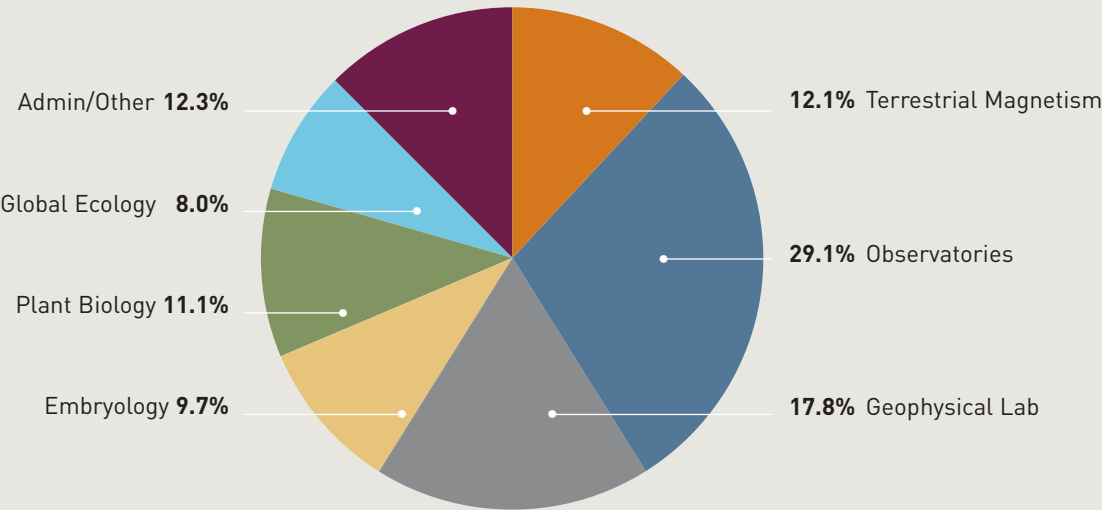
**Statements of Activities<sup>1</sup> (unaudited)**

Periods ended June 30, 2010 and 2009

	2010	2009
Revenue and support:		
Grants and contracts	\$ 42,707,752	\$ 34,257,350
Contributions, gifts	14,255,572	10,102,788
Other income	898,225	31,966,105
Net external revenue	\$ 57,861,549	\$ 76,326,243
Investment income and unrealized gains (losses)	\$ 85,323,573	(\$236,535,117)
Total revenues, gains, other support	\$ 143,185,122	(\$160,208,874)
Program and supporting services:		
Terrestrial Magnetism	\$ 11,210,212	\$ 11,584,642
Observatories	26,961,521	19,460,830
Geophysical Laboratory	16,464,866	14,202,009
Embryology	8,959,492	8,925,327
Plant Biology	10,284,361	10,506,356
Global Ecology	7,378,555	8,087,259
Other programs	915,319	1,273,575
Administration and general expenses	10,495,497	8,654,348
Total expenses	\$ 92,669,823	\$ 82,694,346
Change in net assets before pension related changes	\$ 50,515,299	\$-242,903,220
Pension Related Changes	(53,052)	808,745
Net assets at the beginning of the period	\$686,985,492	\$ 929,079,967
Net assets at the end of the period	\$737,447,739	\$ 686,985,492

<sup>1</sup>Includes restricted, temporarily restricted, and permanently restricted revenues, gains, and other support.

2010 Expenses by Department (\$92.7 Million)



# Personnel

*July 1, 2009-June 30, 2010*

## Carnegie Administration

Benjamin Barbin, *Manager, Advancement Activities*  
 Shaun Beavan, *Systems Administrator*  
 Gloria Brienza, *Manager, Budget and Management Analysis*  
 Donald Brooks, *Building Maintenance Specialist*  
 Marjorie Burger, *Financial Manager*  
 Cady Canapp, *Manager, Human Resources and Insurance*  
 Alan Cutler, *Science Writer*  
 Robert Ellis, *Web Developer*  
 Jason Gebhardt, *Research Assistant*<sup>1</sup>  
 Michelle Fisher, *Special Events and Facility Coordinator*  
 Alexis Fleming, *Special Events and Building Assistant*<sup>2</sup>  
 Shawn Frazier, *Accounting Technician*  
 Dina Freydin, *Senior Grants Accountant*  
 Susanne Garvey, *Director, External Affairs*  
 Darla Keefer, *Special Assistant for Administration and Building Operations*

Ann Keyes, *Payroll Coordinator*  
 Yang Kim, *Deputy Financial Manager*  
 Lisa Klow, *Executive Assistant to the President*  
 George Gary Kowalczyk, *Director, Administration and Finance*  
 Tina McDowell, *Editor and Publications Officer*  
 Richard A. Meserve, *President*  
 June Napoco-Soriente, *Financial Accountant*  
 Mikhail Pimenov, *Manager, Endowment*  
 Arnold J. Pryor, *Facilities Coordinator*<sup>3</sup>  
 Gotthard Sághi-Szabó, *Chief Information Officer*  
 Harminder Singh, *Financial Systems Accountant*  
 Henry Spencer, *Information Technology Intern*<sup>4</sup>  
 John Strom, *Multimedia Designer/Producer*  
 Mira Thompson, *Manager, Advancement Operations*  
 Rohan Vanjara, *Web Developer Intern*<sup>4</sup>

Yulonda White, *Human Resources and Insurance Records Coordinator*  
 Jacqueline Williams, *Assistant to Manager, Human Resources and Insurance*  
 Bryant Zadegan, *Data Analyst Intern*<sup>4</sup>

<sup>1</sup>To May 10, 2010  
<sup>2</sup>From January 25, 2010  
<sup>3</sup>To January 31, 2010  
<sup>4</sup>To August 31, 2009

## Carnegie Academy for Science Education

Bianca Abrams, *Director, Math for America*  
 Faith Ajayi, *CASE Intern*<sup>1</sup>  
 Brianna Anderson, *CASE Intern*<sup>4</sup>  
 Monica Artis, *CASE Intern*<sup>1</sup>  
 Suria Bahadue, *CASE Intern*<sup>1</sup>  
 Sarah Bax, *CASE Mentor*<sup>2</sup>  
 Brittney Bradley, *CASE Intern*<sup>1</sup>  
 Guy Brandenburg, *First Light Instructor, CASE and MfA Mentor*  
 Anne Brooks-Hemphill, *CASE Mentor*<sup>3</sup>  
 Khalid Bullock, *STARS Program Intern*<sup>4</sup>  
 Nicole Cherry, *CASE Intern*<sup>4</sup>  
 Katherine Collins, *Math for America Fellow*  
 Amy Danks, *Math for America Fellow*  
 Victoria Davis, *CASE Intern*<sup>4</sup>  
 Asonja Dorsey, *CASE Mentor*<sup>3</sup>  
 Lanisha Dorsey, *CASE Intern*<sup>1</sup>  
 Lauren Dorsey, *CASE Intern*<sup>4</sup>  
 Steven Dorsey, *CASE Intern*<sup>4</sup>  
 Juwana Douglas, *STARS Program Intern*<sup>4</sup>  
 VanNessa Duckett, *CASE Mentor*<sup>5</sup>  
 Julie Edmonds, *Codirector, CASE*  
 Anne Farrell, *Math for America Fellow*  
 Ricky Garibay, *Intern and First Light Assistant*<sup>5</sup>  
 Samuel Goldstein, *Volunteer*  
 Darcy Hampton, *CASE Mentor*<sup>3</sup>  
 Tashima Hawkins, *CASE Mentor*<sup>3</sup>  
 Gayan Hettipola, *CASE Intern*<sup>1</sup>  
 Krystn Hodge, *Math for America Fellow*  
 Courtney Holmes, *STARS Program Intern*<sup>4</sup>  
 Toby Horn, *Codirector, CASE*  
 Trisha Ibeh, *CASE Intern*<sup>1</sup>  
 Joseph Isaac, *CASE Fellow*<sup>1</sup>  
 Matthew James, *CASE Intern*<sup>4</sup>  
 Linda Jamison, *STARS Program Intern*<sup>4</sup>  
 Marlena Jones, *Coordinator of Programs*

Molley Kaiyoowongs, *Math for America Fellow*  
 M'Heeraw Kennedy, *CASE Intern*<sup>1</sup>  
 Brian Kim, *Research Assistant*<sup>6</sup>  
 Yeelan Ku, *CASE Intern*<sup>1</sup>  
 Sophia Lallinger, *Math for America Fellow*  
 Kaya Lowery, *CASE Intern*<sup>1</sup>  
 Shameka Lyles, *STARS Program Intern*<sup>4</sup>  
 Lindsay Mann, *Math for America Fellow*  
 Jeanah McCall, *CASE Intern*<sup>7</sup>  
 Michael McCreary, *CASE Intern*<sup>1</sup>  
 My'Chelle McCreary, *CASE Intern*<sup>1</sup>  
 Sunday McIlwain, *CASE Intern*<sup>1</sup>  
 Maya Meraz-Garcia, *CASE Mentor*<sup>3</sup>  
 Max Mikulec, *Math for America Fellow*  
 Devonte Miles, *STARS Program Intern*<sup>4</sup>  
 Thomas Nassif, *CASE Mentor*<sup>8</sup>  
 Maximilian Olivier, *Math for America Fellow*  
 Yolande Paho, *CASE Intern*<sup>1</sup>  
 Julia Penn, *Math for America Fellow*  
 Jessica Reynolds, *Math for America Fellow*  
 Debron Rodney, *CASE Intern*<sup>9</sup>  
 Corshelle Rowland, *CASE Intern*<sup>10</sup>  
 Brittney Sims, *CASE Intern*<sup>1</sup>  
 John Solano, *CASE Fellow*<sup>11</sup>  
 Liza Styles, *Math for America Fellow*<sup>12</sup>  
 Dashawn Taylor, *STARS Program Intern*<sup>13</sup>  
 Jasmine Thomas, *STARS Program Intern*<sup>4</sup>  
 Tierra Thornton, *STARS Program Intern*<sup>4</sup>  
 Samuel Trichtinger, *Math for America Fellow*  
 Meredith Wachs, *Math for America Fellow*  
 Juna Wallace, *Intern and First Light Assistant*<sup>1</sup>  
 Brittany Warren, *STARS Program Intern*<sup>4</sup>  
 Isaiah West, *CASE Intern*<sup>14</sup>  
 DeVaughn Wilson, *STARS Program Intern*<sup>4</sup>  
 Heather Zelinsky, *Math for America Fellow*

<sup>1</sup>To August 31, 2009  
<sup>2</sup>From June 1, 2010  
<sup>3</sup>To July 31, 2010  
<sup>4</sup>From June 28, 2010, to August 5, 2010  
<sup>5</sup>From June 1, 2010, to August 24, 2010  
<sup>6</sup>From June 21, 2010, to August 5, 2010  
<sup>7</sup>From September 08, 2009, to August 5, 2010  
<sup>8</sup>From June 1, 2010, to August 24, 2010  
<sup>9</sup>From June 18, 2010, to August 5, 2010  
<sup>10</sup>From July 20, 2009, to July 30, 2009  
<sup>11</sup>From June 28, 2010, to July 31, 2010  
<sup>12</sup>To September 26, 2009  
<sup>13</sup>From June 28, 2010, to August 4, 2010  
<sup>14</sup>From July 20, 2009, to August 31, 2009



**EMBRYOLOGY** Front row (left to right): Alex Bortvin, Chen-Ming Fan, Allan Spradling, Steve Farber, David MacPherson, Marnie Halpern. Second row: Xiaohong Ma, Brittany Hay, Estela Monge, Ella Jackson, Glenese Johnson, Patricia Cammon, Samantha Satchell. Third row: Erin Gunter, Junqi Zhang, Jianjun Sun, Ming-Chia Lee, Karina Conkrite, Mary Bradford, Michelle Macurak, Rosa Miyares. Fourth row: Eugenia Dikovskaia, Susan Artes, Lydia Li, Lakishia Smith, William Yarosh, Dolly Chin, Ona Martin, Keisha Breland. Fifth row: Alexis Marianes, Svetlana Deryusheva, Allen Strause, Vicki Losick, Itay Onn, Dean Calahan, Dianne Stewart, Becky Frederick. Sixth row: Wilbur Ramos, Amy Kowalski, Alexander Chin, Jen Anderson, Mike Sepanski, Tim Mulligan, Tim Sibiski, Youngjo Kim, Juliana Carten, Katherine Lovette, Valerie Butler, Arash Adeli, Rob Vary, Tagide deCarvalho, Neda Muzaffar, Rejeanne Juste. Seventh row: Maggie Sundby, Pedram Nozari, Pavol Genzor, Bob Levis, Don Fox, Carol Davenport, James Walters, Lei Lei, Ben Goodman, Axel Horn, Lucilla Facchin, Safia Malki, Julio Castaneda. Eighth row: Mahmud Siddiqi, Eugene Gardner, Lucy Morris, Dan Gorelick, Tom McDonough, Shusheng Wang.

## Embryology

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Steven Farber  
Joseph G. Gall  
Marnie Halpern  
Douglas E. Koshland<sup>1</sup>  
Allan C. Spradling, *Director*  
Yixian Zheng

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Svetlana Deryusheva, *Visiting Scientist, Carnegie*  
Lucilla Facchin, *Eppley Foundation Grant (Halpern) and Carnegie Fellow*  
Donald Fox, *Jane Coffin Childs Fellowship*

Rebecca Frederick, *American Cancer Society Fellowship*  
Mary Goll, *Damon Runyon Cancer Research Fellowship*  
Daniel Gorelick, *Carnegie Fellow*  
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Godfried Van der Heijden, *Carnegie Fellow*<sup>11</sup>  
James Walters, *American Cancer Society Fellow*

Shusheng Wang, *Research Associate, NIH Grant (Zheng)*  
 Zheng-an Wu, *Special Investigator, NIH Grant (Gall) and Carnegie Fellow*  
 Cheng Xu, *Carnegie Fellow and NIH Grant (Fan)*

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 Pavol Genzor, *The Johns Hopkins University*  
 Ben Goodman, *The Johns Hopkins University*  
 Jill Heidinger, *The Johns Hopkins University*<sup>13</sup>  
 Margaret Hoang, *The Johns Hopkins University*  
 Kate Lannon, *The Johns Hopkins University*<sup>14</sup>  
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 Lydia Li, *The Johns Hopkins University*<sup>15</sup>  
 Peter Lopez, *The Johns Hopkins University*  
 Alexis Marianes, *The Johns Hopkins University*  
 David Martinelli, *The Johns Hopkins University*<sup>16</sup>  
 Vanessa Matos-Cruz, *The Johns Hopkins University*  
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 Katherine Mitchell, *The Johns Hopkins University*  
 Rosa Miyares, *The Johns Hopkins University*  
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 Amy Herbert, *Student Volunteer*<sup>34</sup>  
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 Connie Jewell, *Systems Administrator*  
 Glenese Johnson, *Laboratory Helper*  
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 Megan Kutzer, *Technician*  
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 Megan Reid, *Laboratory Assistant*<sup>42</sup>  
 Victoria Robinson, *Student Assistant*<sup>43</sup>  
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 Anying Zhang, *Visiting Scientist*<sup>49</sup>  
 Junqi Zhang, *Visiting Scientist*<sup>50</sup>

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 Samer Hattar, *Department of Biology, The Johns Hopkins University*  
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 Roger Hoskins, *Lawrence Berkeley National Laboratory*  
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 Milena Vuica, *Department of Pathology, The Johns Hopkins University School of Medicine*

<sup>1</sup>To June 30, 2010  
<sup>2</sup>To October 27, 2009  
<sup>3</sup>To October 12, 2009  
<sup>4</sup>To June 30, 2010  
<sup>5</sup>From May 3, 2010  
<sup>6</sup>From March 1, 2010

<sup>7</sup>To June 30, 2010  
<sup>8</sup>To August 5, 2009  
<sup>9</sup>To December 31, 2009  
<sup>10</sup>To June 30, 2009  
<sup>11</sup>To May 31, 2010  
<sup>12</sup>From May 24, 2010  
<sup>13</sup>To May 31, 2010  
<sup>14</sup>To October 31, 2009  
<sup>15</sup>From May 24, 2010  
<sup>16</sup>To September 30, 2009  
<sup>17</sup>To May 22, 2010  
<sup>18</sup>From May 24, 2010  
<sup>19</sup>From May 24, 2010  
<sup>20</sup>To June 30, 2010  
<sup>21</sup>From May 24, 2010  
<sup>22</sup>To September 10, 2009  
<sup>23</sup>To September 10, 2009  
<sup>24</sup>From May 25, 2010  
<sup>25</sup>To September 18, 2009  
<sup>26</sup>To June 30, 2010  
<sup>27</sup>To July 31, 2009  
<sup>28</sup>To June 30, 2010  
<sup>29</sup>To July 2, 2009  
<sup>30</sup>From May 24, 2010  
<sup>31</sup>To September 4, 2009  
<sup>32</sup>To April 4, 2010  
<sup>33</sup>From May 23, 2010  
<sup>34</sup>From January 20, 2010  
<sup>35</sup>To June 30, 2010  
<sup>36</sup>From April 12, 2010  
<sup>37</sup>From August 19, 2009  
<sup>38</sup>To July 12, 2009  
<sup>39</sup>To December 4, 2009  
<sup>40</sup>From March 29, 2010  
<sup>41</sup>To April 6, 2010  
<sup>42</sup>From May 17, 2010  
<sup>43</sup>To August 2009  
<sup>44</sup>To August 15, 2009  
<sup>45</sup>From October 12, 2009  
<sup>46</sup>To July 28, 2009  
<sup>47</sup>To August 12, 2009  
<sup>48</sup>From June 1, 2010  
<sup>49</sup>To October 28, 2009  
<sup>50</sup>From October 27, 2009

## Geophysical Laboratory

### Staff Scientists

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 Douglas Rumble III  
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### NSF REU Program Director and CDAC Laboratory Manager

Stephen A. Gramsch

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**GEOPHYSICAL LABORATORY** Front row (left to right): Yingwei Fei, Neil Irvine, Anat Shahar, George Cody, Robert Hazen, Russell Hemley, Ronald Cohen, Bjørn Mysen, Andrew Steele, Alexander Goncharov. Second row: David Baker, Roxane Bowden, Danielle Appleby, Lauren Cryan, Yufei Meng, Kadek Hemawan, Liwei Deng, Yoko Kebukawa, Takamitsu Yamanaka, Jinfu Shu, Namhey Lee, Dina Bower, Weifu Guo, Nabil Boctor, Yuki Nakamoto. Third row: Constance (Connie) Bertka, Gefei Qian, Andrea Mangum, Dyanne Furtado, Shaun Hardy, Morgan Phillips, Gary Bors, Mihaela Glamoclija, Pamela Woodard, Atsushi Kyono, Joseph Lai, Jeff Lightfield, Trong Nguyen, Reinhard Boehler, Stephen Coley, Valerie Hillgren, Merri Wolf, Douglas Allen Dalton, Li Zhang, Ying Wang, Stewart McWilliams, Christopher Seagle, Timothy Strobel, Liuxiang Yang, Malcolm Guthrie, Robert (Jerry) Potter. Back row: Muhetaer Aihaiti, Shohei Ohara, Henderson James (Jim) Cleaves, Kateryna Klochko, Marilyn (Helen) Venzon, Victor Lugo, Stephen Hodge, Daniel Hummer, Adrian Villegas-Jimenez, Derek Smith, Chi Zhang, Amol Karandikar.

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 Junyue Wang, *Postdoctoral Researcher, HPSynC and ANL*<sup>17</sup>  
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 Henderson James Cleaves II, *Project Manager, DCO*<sup>23</sup>  
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 Kateryna Klochko, *Postdoctoral Associate, NAI and NSF*<sup>33</sup>

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 Xuan Luo, *Postdoctoral Associate, NSF*<sup>35</sup>  
 Francis McCubbin, *Carnegie Fellow*<sup>36</sup>  
 Yufei Meng, *Postdoctoral Associate*  
 Javier Antonio Montoya Martinez, *Carnegie Fellow*<sup>37</sup>  
 Subramanian Natarajan, *Postdoctoral Associate, DOE*<sup>38</sup>  
 Shohei Ohara, *Postdoctoral Associate, NSF*  
 Julius Ojwang, *Carnegie Fellow*<sup>39</sup>  
 Dominic Papineau, *Postdoctoral Associate, NSF*  
 Angèle Ricolleau, *Carnegie Fellow, NSF*<sup>40</sup>  
 Christopher Seagle, *Carnegie Fellow*<sup>41</sup>  
 Luke Shulenburg, *Postdoctoral Associate, NSF*<sup>42</sup>  
 Timothy Strobel, *Carnegie Fellow, NSF*  
 Ying Wang, *Carnegie Fellow*<sup>43</sup>  
 Li Zhang, *Postdoctoral Associate, NASA*

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 Clare Flynn, *Predocutorial Fellow, NSF-NASA*<sup>46</sup>  
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 Amol Karandikar, *Predocutorial Associate, EFree*<sup>48</sup>  
 Namhey Lee, *Predocutorial Fellow, The Johns Hopkins University*  
 Verena Starke, *NASA Marshall Space Flight Center*

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 Alaina Beres, *Elmhurst College*<sup>51</sup>  
 Thomas Hittinger, *Howard University*<sup>52</sup>  
 Yasmin Kadry, *Howard University*<sup>53</sup>  
 Brendan O'Connor, *Montgomery College*<sup>54</sup>  
 Olaoluwa Omotosho, *Howard University*<sup>55</sup>

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 Breana Hashman, *Dickinson College*  
 Rachael Hoover, *University of Colorado*  
 Benjamin Horkley, *Wilson High School/Massachusetts Institute of Technology*  
 Byron Kelly, *Memorial University of Newfoundland*  
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 Jennifer Moses, *Franklin and Marshall College*  
 Donald Plattner, *Centre College*  
 Michael Wong, *University of California, Berkeley*

### High School Interns

Obioma Anomnachi, *The Field School*  
 Ari-jan Azad, *British School of Washington*  
 Thomas Gramsch, *Lake Braddock High School*  
 Winston Liu, *Montgomery Blair High School*  
 Hannah Moore, *Albert Einstein High School*  
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 Maimon Rose, *Melvin J. Berman Hebrew Academy*  
 Søren Scott, *Bethesda Chevy Chase High School*

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 Maceo T. Bacote, *Building Engineer*<sup>56</sup>  
 David Black, *Library Assistant*<sup>57</sup>  
 Gary A. Bors, *Building Engineer*<sup>58</sup>  
 Roxane Bowden, *Lab Manager, Stable Isotope Facility*<sup>59</sup>  
 Bobbie L. Brown, *Instrument Maker*<sup>60</sup>  
 Stephen D. Coley, Sr., *Instrument Shop Supervisor*  
 Lauren Cryan, *DCO Program Assistant*<sup>61</sup>  
 Roy R. Dingus, *Facility Manager*<sup>62</sup>  
 Pablo D. Esparza, *Maintenance Technician*<sup>63</sup>  
 Dyanne Furtado, *Staff Accountant*  
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 Shaun J. Hardy, *Librarian*<sup>64</sup>  
 Stephen Hodge, *Instrument Maker*  
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 Lauren Kerr, *Research Technician, Charles River Grant*<sup>65</sup>  
 William E. Key, *Building Engineer*<sup>66</sup>  
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 Joseph Lai, *CVD Diamond Lab Manager*  
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 Andrea Mangum, *DCO Program Associate*<sup>67</sup>  
 Fabian Moscoso, *Building Engineer Apprentice*<sup>68</sup>  
 Susana Mysen, *Technical Assistant*<sup>69</sup>  
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 Scott Price, *Electronics Specialist*  
 Gefei Qian, *Systems Administrator*  
 Pedro J. Roa, *Maintenance Technician*<sup>70</sup>  
 Haiyun (Kevin) Shu, *CVD Diamond Technician*  
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 Merri Wolf, *Library Technical Assistant*<sup>71</sup>  
 Pamela L. Woodard, *Web/Departmental Assistant*<sup>72</sup>  
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<sup>1</sup>From July 1, 2009

<sup>2</sup>From August 17, 2009

<sup>3</sup>From September 1, 2009

<sup>4</sup>To September 30, 2009; EFree neutron scientist from October 1, 2009

<sup>5</sup>From March 1, 2010

<sup>6</sup>From September 21, 2009

<sup>7</sup>From January 4, 2010

<sup>8</sup>To September 4, 2009

<sup>9</sup>To August 21, 2009

<sup>10</sup>From January 18, 2010

<sup>11</sup>From September 1, 2009

<sup>12</sup>From August 2009, to January 2010

<sup>13</sup>To February 21, 2010

<sup>14</sup>From September 15, 2009

<sup>15</sup>To October 8, 2009

<sup>16</sup>From April 15, 2010

<sup>17</sup>From July 2009

<sup>18</sup>To April 14, 2010; research scientist at HPSynC from April 15, 2010

<sup>19</sup>To September 30, 2009; HPSynC co-project manager from October 1, 2009

<sup>20</sup>From April 1, 2010

<sup>21</sup>From January 4, 2010

<sup>22</sup>To April 25, 2010

<sup>23</sup>From November 1, 2007, to July 30, 2009; visiting investigator from August 1, 2009

<sup>24</sup>From August 26, 2009

<sup>25</sup>To June 30, 2010

<sup>26</sup>To February 28, 2010

<sup>27</sup>From August 31, 2009

<sup>28</sup>From March 22, 2010

<sup>29</sup>To October 26, 2009

<sup>30</sup>To October 31, 2009

<sup>31</sup>To June 30, 2010; moved to HPSynC

<sup>32</sup>To October 30, 2009

<sup>33</sup>From July 14, 2009

<sup>34</sup>To August 31, 2009

<sup>35</sup>To September 9, 2009; visiting investigator from April 15, 2010

<sup>36</sup>From July 1, 2009, to June 30, 2010

<sup>37</sup>To January 31, 2010

<sup>38</sup>To March 10, 2010

<sup>39</sup>From July 1, 2009

<sup>40</sup>To September 19, 2009; joint IMPMC-GL Fellow from March 1, 2009, to September 18, 2009

<sup>41</sup>From August 7, 2009

<sup>42</sup>To June 30, 2010

<sup>43</sup>From November 20, 2009

<sup>44</sup>To July 31, 2009

<sup>45</sup>From June 1, 2010

<sup>46</sup>To August 31, 2009

<sup>47</sup>To August 31, 2009; research assistant from September 1, 2009

<sup>48</sup>From March 26, 2010

<sup>49</sup>From June 16, 2010

<sup>50</sup>From January 4, 2010, to January 18, 2010

<sup>51</sup>From June 8, 2010

<sup>52</sup>From June 15, 2010

<sup>53</sup>From June 15, 2010

<sup>54</sup>To August 31, 2009

<sup>55</sup>From May 24, 2010

<sup>56</sup>Joint appointment with DTM

<sup>57</sup>January 1, 2010, to April 21, 2010

<sup>58</sup>Joint appointment with DTM

<sup>59</sup>From September 23, 2009

<sup>60</sup>To May 10, 2010

<sup>61</sup>From October 20, 2009

<sup>62</sup>Joint appointment with DTM

<sup>63</sup>Joint appointment with DTM

<sup>64</sup>Joint appointment with DTM

<sup>65</sup>To August 17, 2009

<sup>66</sup>Joint appointment with DTM

<sup>67</sup>From June 1, 2010

<sup>68</sup>Joint appointment with DTM

<sup>69</sup>To July 30, 2009; EFree project administrator from August 1, 2009

<sup>70</sup>Joint appointment with DTM

<sup>71</sup>Joint appointment with DTM

<sup>72</sup>From September 1, 2009

## Global Ecology

### Research Staff Members

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 Eben Broadbent, *Stanford University*  
 Matthew Colgan, *Stanford University*  
 Kyla Dahlin, *Stanford University*



**GLOBAL ECOLOGY** Front row (left to right): Luis Fernandez, Naoia Williams, Evana Lee, Michael Dini, Jan Brown, Mike Mascaro, Guayana Paez-Acosta, Marion O'Leary, Kelly McManus, Dahlia Wist, Hulya Aksoy, Mona Houcheime, Tuia Williams. Second row: Ken Caldeira, David Knapp, Amy Wolf, Angelica Vasquez, Linda Longoria, Larry Giles, Jennifer Johnson, Lena Perkins, Katharine Mach, Ismael Villa. Third row: Turken Eke, Kathi Bump, John Clark, Robin Martin, Bill Anderegg, Julia Pongratz, Matt Colgan, Long Cao, Rebecca Hernandez, Aravindh Balaji, Kyla Dahlin, Todd Tobeck, Mike Mastrandrea, Eric Kissel, Paul Sterbentz. Fourth row: Chris Field, Greg Asner, James Jacobson, Chris Anderson, Jean-Baptiste Feret, Kevin Smith, Scott Loarie, Joe Berry, Shane Easter, Ijah Garfield, Ty Kennedy-Bowdoin.

Luis Fernandez, *Stanford University*<sup>5</sup>  
 Eve-Lyn Hinckley, *Stanford University*<sup>6</sup>  
 Jennifer Johnson, *Stanford University*  
 Claire Lunch, *Stanford University*<sup>7</sup>  
 Alex Nees, *Stanford University*  
 Carolyn Snyder, *Stanford University*<sup>8</sup>  
 Adam Wolf, *Stanford University*

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 Devon Arscott, *Intern*<sup>9</sup>  
 Aravindh Balaji, *Computer Technician*  
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 Angela Torney, *Laboratory Assistant*  
 C. Parker Weiss, *Laboratory Technician*

<sup>1</sup>To June 1, 2010

<sup>2</sup>From February 16, 2010

<sup>3</sup>From July 1, 2009

<sup>4</sup>To September 1, 2009

<sup>5</sup>From October 1, 2009

<sup>6</sup>To September 15, 2009

<sup>7</sup>To June 15, 2010

<sup>8</sup>To March 31, 2010

<sup>9</sup>From July 1, 2009, to April 30, 2010

<sup>10</sup>To September 30, 2009

<sup>11</sup>To June 30, 2010

<sup>12</sup>From May 1, 2010

<sup>13</sup>From October 1, 2009

<sup>14</sup>To October 31, 2009

<sup>15</sup>To June 22, 2010

<sup>16</sup>To August 31, 2009

<sup>17</sup>To February 15, 2010

<sup>18</sup>To December 31, 2009

<sup>19</sup>To August 30, 2009

<sup>20</sup>To November 1, 2009

<sup>21</sup>To December 31, 2009

<sup>22</sup>From February 16, 2010

<sup>23</sup>From August 11, 2009, to September 15, 2009

## The Observatories

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George Preston, *Director Emeritus*  
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David Floyd, *Magellan Fellow*<sup>12</sup>  
Gaston Folatelli, *Postdoctoral Fellow*  
Maximilian Stritzinger, *Postdoctoral Fellow*<sup>13</sup>  
Shane Walsh, *AAO Magellan Fellow*<sup>14</sup>

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### Support Scientist

David Murphy, *Instrument Scientist*

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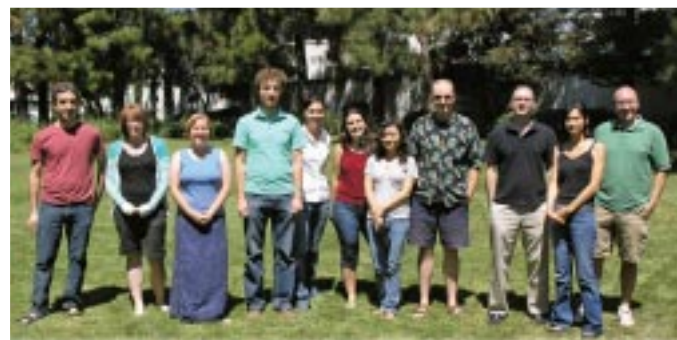
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<sup>2</sup>From October 1, 2009

<sup>3</sup>From April 1, 2010; formerly Carnegie Fellow

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<sup>7</sup>From October 15, 2009

<sup>8</sup>To July 24, 2009

<sup>9</sup>To August 14, 2009

<sup>10</sup>To November 14, 2009

<sup>11</sup>From August 3, 2009

<sup>12</sup>To August 12, 2009

<sup>13</sup>To June 30, 2010

<sup>14</sup>From July 20, 2009

<sup>15</sup>To March 1, 2010

<sup>16</sup>To December 31, 2009

<sup>17</sup>From April 1, 2010

<sup>18</sup>From January 4, 2010

<sup>19</sup>From May 3, 2010

<sup>20</sup>From May 24, 2010

<sup>21</sup>From July 14, 2009

<sup>22</sup>From April 15, 2010

<sup>23</sup>To August 31, 2009

<sup>24</sup>To April 30, 2010

<sup>25</sup>From June 7, 2010

<sup>26</sup>To April 16, 2010

<sup>27</sup>To May 10, 2010

<sup>28</sup>To March 31, 2010

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## Plant Biology

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<sup>2</sup>To March 10, 2010  
<sup>3</sup>From January 8, 2010  
<sup>4</sup>From June 1, 2010  
<sup>5</sup>To May 31, 2010  
<sup>6</sup>From February 1, 2010  
<sup>7</sup>To August 14, 2009  
<sup>8</sup>To November 30, 2009  
<sup>9</sup>From December 1, 2009  
<sup>10</sup>To June 22, 2010  
<sup>11</sup>To May 28, 2010  
<sup>12</sup>From August 1, 2009  
<sup>13</sup>To December 21, 2009  
<sup>14</sup>To December 17, 2009  
<sup>15</sup>From February 22, 2010  
<sup>16</sup>To October 31, 2009  
<sup>17</sup>From November 1, 2009  
<sup>18</sup>From September 1, 2009  
<sup>19</sup>To July 31, 2009  
<sup>20</sup>To September 15, 2009  
<sup>21</sup>To March 26, 2010  
<sup>22</sup>To November 24, 2009  
<sup>23</sup>From May 3, 2010  
<sup>24</sup>To July 1, 2009  
<sup>25</sup>From July 6, 2009  
<sup>26</sup>To August 17, 2009  
<sup>27</sup>To June 9, 2010  
<sup>28</sup>From August 13, 2009  
<sup>29</sup>From March 1, 2010  
<sup>30</sup>From October 27, 2009  
<sup>31</sup>From May 16, 2010  
<sup>32</sup>To August 31, 2009  
<sup>33</sup>To September 1, 2009  
<sup>34</sup>From June 22, 2010  
<sup>35</sup>From July 1, 2009, to August 31, 2009  
<sup>36</sup>From July 1, 2009, to September 18, 2009  
<sup>37</sup>From June 30, 2010  
<sup>38</sup>From June 8, 2010  
<sup>39</sup>From June 12, 2010  
<sup>40</sup>From June 10, 2010  
<sup>41</sup>To January 31, 2010  
<sup>42</sup>From January 18, 2010  
<sup>43</sup>To April 22, 2010  
<sup>44</sup>From January 6, 2010  
<sup>45</sup>To June 30, 2010  
<sup>46</sup>To April 30, 2010  
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<sup>2</sup>From November 16, 2009

<sup>3</sup>From October 19, 2009

<sup>4</sup>To December 31, 2009

<sup>5</sup>From September 1, 2009

<sup>6</sup>From October 1, 2009

<sup>7</sup>From October 1, 2009

<sup>8</sup>To April 21, 2010

<sup>9</sup>From January 11, 2010

<sup>10</sup>To December 31, 2009

<sup>11</sup>Deceased November 22, 2009

<sup>12</sup>From June 1, 2010

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<sup>14</sup>To August 12, 2009

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July 1, 2009 - June 30, 2010

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## DEPARTMENT OF TERRESTRIAL MAGNETISM

Here updated through September 30, 2010.

The list is regularly updated on the DTM web site (<http://www.dtm.ciw.edu>).

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